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ICAL WARFARE LABORATORIES

TECHNICAL REPORT

CWLR 2075

DEVELOPMENT OF THE E6 GAS WARHEAD
THE B-61A MATADOR PILOTLESS BOMBER (U)

by

Thomas W. Tranberg

19 February 1957

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Project 4-16-16-011 (CONFIDENTIAL)

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Chemical Corps Research and Development Command
CHEMICAL WARFARE LABORATORIES
Army Chemical Center, Maryland

Chemical Warfare Laboratories Report No. 2075

Directorate of Development

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FOR THE B-61A MATADOR PILOTLESS BOMBER (U)

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Chemical Warfare Laboratories
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APPROVED:

DEVELOPMENT OF THE E6 GAS WARHEAD
FOR THE B-61A MATADOR PILOTLESS BOMBER (U)

Project No.: 4-16-16-011
Notebook Nos.: 2840, 3411

Donald E Yanka

DONALD E. YANKA
Colonel, CmlC
Director of Development

Date Started: 23 May 1951
Date Completed: 23 August 1954

Date Submitted: 4 April 1956

S. D. Silver

S.D. SILVER
Deputy Commander for
Scientific Activities

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ABSTRACT

Object.

The object of project 4-16-16-011 was to design and develop a 3,000-lb. nonpersistent-gas warhead and all related fuzing, handling equipment, and shipping equipment for the B-61A MATADOR pilotless bomber (see fig. 1).

The object of the work described in this report was to study the problems related to the development of a gas warhead for a 500-mi.-range, surface-to-surface, subsonic, tactical guided missile of the B-61A configuration; to produce designs of such a warhead and its related support equipment; and to conduct the development tests necessary to bring the project to a state of readiness for the final engineering test.

Results.

The effort resulted in the design and partial test of a gas warhead and all of the equipment required for the assembly, storage, transportation, and tactical employment of the gas warhead. The following is a complete list of components which were designed and, in most instances, partially tested:

1. E6 3,000-lb. nonpersistent-gas warhead
2. E125 3,000-lb. nonpersistent-gas cluster
3. E54 3,000-lb. cluster adapter
4. T1404 mechanical time fuze
5. Cluster assembly rack
6. Cluster handling clamp
7. Shipping container, hermetically sealed
8. Warhead handling sling
9. Warhead loading stand

Cancellation of the project curtailed the completion of tests and such redesign as may have been required, but usage in the field in support of the flight test program gave strong indication that the items, with the exception of the shipping container, were satisfactory. The first shipping container has not been received from the contractor, so no evaluation has been possible.

Six fin-stabilized warheads were released from B-36F aircraft of which two failed to function, two functioned in an abnormal manner, and two functioned normally. Bomblet patterns obtained from the four functioning warheads indicated that ground coverage was considerably less than the desired goal of 106,000 sq.yd.

The following data summarized the conditions of release and results obtained from each test vehicle:

Table 1

Summary of Performance on E6 Gas Warhead

Warhead no.	87A-1	87A-3 (a)	87A-4	87A-5	87A-6 (a)	87A-7
Release altitude, ft.	36,890	35,942	35,870	35,499	35,825	37,010
Release velocity, f.p.s.	558	523	452	490	429	550
Separation altitude, ft.	16,590	--	13,390	15,680	--	12,100
Separation velocity, f.p.s.	1,059	--	990	1,030	--	1,073
Range:						
Release to separation, ft.	18,810	25,095 (b)	13,495	15,706	17,635 (b)	20,190
Separation to impact, ft.	3,000		2,250	687	--	1,890
Ballistic wind:						
Range, f.p.s.	-6.34	--	-1.11	-13.71	--	-4.81
Cross, f.p.s.	6.48	--	-30.46	-8.11	--	7.10
Munition	E54R6	E54R6	E54R6	E54R6	E54R6	E54R6
No. munitions	306	306	306	306	306	306
Pattern dimensions, yd.	320 x 320	--	835 x 335	350 x 285	--	335 x 335
Recovery, %	97	--	98	97	--	90
2σ (c) range, yd.	125.19	--	257.24	128.18	--	140.08
2σ deflection, yd.	113.91	--	110.28	106.96	--	139.97
2σ area, sq.yd.	44,800	--	89,100	43,070	--	61,600
2σ area, %	84	--	87	81	--	85
Pattern coefficient, D/R	0.91	--	0.43	0.83	--	0.999

(a) Failed to function.
(b) Total range from release to impact.
(c) σ = Standard deviation.

The T1404 fuze, although not used as the prime fuze system in the flight tests, functioned successfully during the flight tests and in the limited static tests conducted. The fuze had not been subjected to a complete environmental test program prior to termination of the project, but indications were that the fuze could successfully be used in the test program with no more than minor changes required, if any.

Conclusions.

1. A complete gas warhead system for the B-61A missile has been designed and partially tested. However, indications are that the toxic coverage attained falls short by approximately 50% of the potential capability of a warhead of this design.

2. A new approach to the problem incorporating some type of dispersion mechanism or a new self-dispersing munition would be necessary to achieve a better coverage of the target with agent.

3. The large errors which exist in the terminal dive phase of the B-61A missile at the present time make it questionable whether any reasonable degree of accuracy can be achieved utilizing the E54R6 bomblet.

Recommendations.

None, since the project has been canceled and no further effort will be applied.

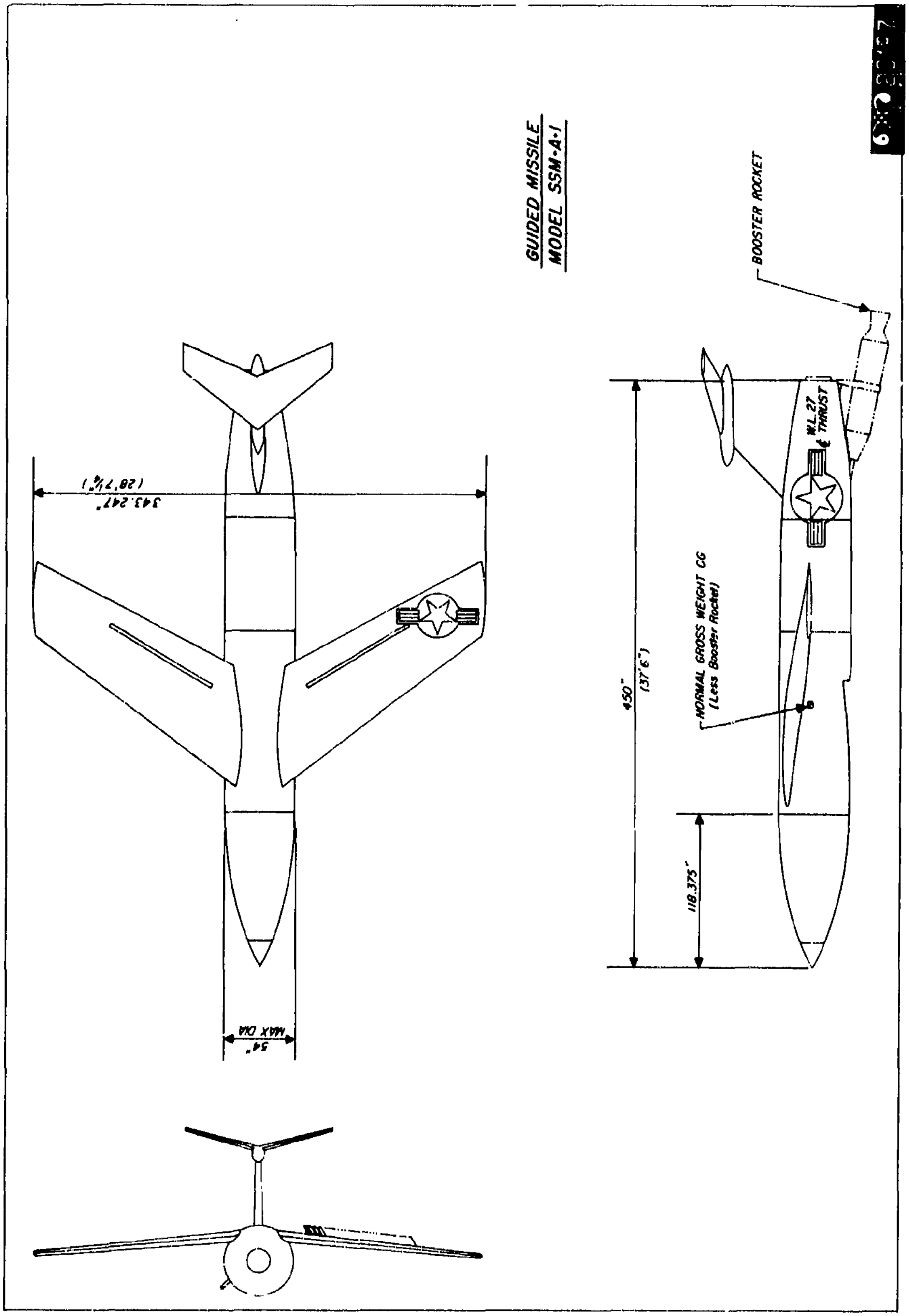

FIGURE 1

B-61A MISSILE

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DEVELOPMENT OF THE E6 GAS WARHEAD FOR THE B-61A MATADOR PILOTLESS BOMBER (U)

I. INTRODUCTION.

A. Object.

The object of project 4-16-16-011 was to design and develop a 3,000-lb. nonpersistent-gas warhead and all related fuzing, handling equipment, and shipping equipment for the B-61A MATADOR pilotless bomber.

The object of the work described in this report was to study the problems related to the development of a gas warhead for a 500-mi.-range, surface-to-surface, subsonic tactical guided missile of the B-61A configuration; to produce designs of such a warhead and its related support equipment; and to conduct the development tests necessary to bring the project to a state of readiness for final engineering test.

B. Authority.

The authority for this work is given under Project 4-16-16-011, GB Warhead for MX-771 Missile, which was established on 25 May 1951 (CCTC Item 2325, Establishment of 67 New Projects in the FY 1952 Chemical Corps Program). The project was canceled on 9 December 1954 (CCTC Item 2962, Consolidation of Chemical Corps CW R&D Program for FY 55).

II. HISTORICAL.

Investigation of chemical warheads for the MATADOR missile was initiated during fiscal year 1948 under Project 4-16-06-01, Chemical Warheads for Guided Missiles. This work was continued under Project 4-16-16-02, Warheads for MX-771 Missile, established 19 November 1948 (CCTC Item 1931). The results of the work completed under the above projects are reported in detail in Guided Missile Reports 1 through 18 and will not be repeated here.

The work conducted under project 4-16-16-02 was related to Phase I of the prime missile contract, the XSS-A-1 (experimental) XB-61 missile, and Phase II, YSSM-A-1 (limited production) YB-61.

On 28 November 1950 representatives of Headquarters, USAF, met at Chemical and Radiological Laboratories to discuss the future of the MATADOR warhead program. At this meeting the Air Force placed emphasis on development of a nonperistent-gas warhead, to be made available by the spring of 1952.

During fiscal year 1951 the Glenn L. Martin Company, prime contractor for the MATADOR missile, completed Phase II of the missile program and initiated Phase III, comprising fabrication and test of the production missile, the B-61A (i.e., the MATADOR). In the course of the redesign for production, the configuration was changed considerably, and the existing designs for the gas warhead were obsoleted. This report covers all that has been done during this period on the development and testing of the GB warhead for the MATADOR.

Work not completed under project 4-16-16-02 was carried over and conducted simultaneously with project 4-16-16-011. This consisted of the dynamic testing of three remaining fin-stabilized warheads of the YSSM-A-1 configuration.

A gas cluster containing 275 E54R6 bombs was designed, fabricated, assembled, and flight-tested in August 1951 by the use of the YSSM-A-1 fin-stabilized warhead test vehicle. Individual munition functioning was unusually poor, and further testing was suspended, pending availability of an improved unit munition. This munition, the E54R6, was clustered and assembled in two additional YSSM-A-1 fin-stabilized warheads. The first of the two test vehicles functioned normally, and a complete pattern was obtained. The second test vehicle failed to open for reasons never completely established and impacted intact.

A specific program for the development of a gas warhead for the MATADOR was established on 25 May 1951 (CCTC Item 2325, Project 4-16-16-011, GB Warhead for MX-771 Missile).

III. ANALYSIS OF THE PROBLEM.

A. Military Characteristics.

The military characteristics governing the development of the GB warhead for MX-771 missile are contained in CCTC Item 2483, Continuation of 271 Projects in the Chemical Corps FY 1953 Program and Revisions Thereto, approved 23 June 1952. They are as follows:

1. The warhead shall be capable of:

a. Establishing a lethal dosage of GB in 30 seconds over the maximum area possible.

b. Achieving reproducible ballistics.

c. Distribution of individual munitions at a speed of Mach 0.9 to 1.2.

2. The warhead shall be designed to:

a. Conform to the warhead space and shape available in the MATADOR missile.

b. A weight of 3,000 lb. ± 150 lb. Ballast may be used if necessary.

c. Be interchangeable in the MATADOR with other warheads specified in SSM-M/C2A, dated 16 August 1950.

d. Be capable of secure attachment to the missile within 30 minutes by a trained crew and thereafter be ready for firing within an additional 10 minutes.

e. Be capable of all-weather employment within the limits of the agent filling.

f. Be stored under uncontrolled temperature and humidity conditions for at least 5 years without deterioration to the extent that the warhead, exclusive of agent filling, is rendered unserviceable.

g. Be safe to handle and store, requiring no special handling equipment other than that required for handling HE warheads.

h. Be transportable by all conventional military transportation methods.

i. Be provided with a reliable fuzing system capable of opening the warhead at any desired altitude over the target within the operational limits of the MATADOR missile.

B. Factors to Be Considered.

1. Comments on the Military Characteristics.

From a warhead design viewpoint these military characteristics are written broadly enough to allow considerable freedom in establishing a warhead concept. Weight and space considerations posed no particular problem in the light of past experience with the YSSM-A-1 missile nor did interchangeability with other warheads. The design aspects appear to be generally straightforward.

Actually, the entire program is an extension of the work previously accomplished in connection with the YSSM-A-1 missile and no radical changes are anticipated. This course of action is due mainly to the shortened development time allowed by the missile schedule established by the Air Force. Here the emphasis lay on delivering a complete and acceptable warhead system in advance of the phase-out date for the missile. The original date for completion of the development phase was set for June 1953 (although this schedule and the missile schedule both slipped considerably later on), allowing approximately 2 yr. for the complete development of the warhead. This, obviously, was not time enough to conduct a thorough and comprehensive investigation into various systems for carrying and dispersing the unit munitions. For this reason the only approach was along the same lines as were followed on the YSSM-A-1 missile.

The warhead would consist of a simplified method for containing the unit munitions and a simplified and more reliable opening system. This concept, as in previous development work, would not incorporate any special devices for aiding in the dispersion of the unit munitions.

Together with the warhead itself there would be certain other items of support equipment such as clustering fixtures, shipping container, hoist slings, assembly stands, and an array of conventional portable tools necessary for the assembly and handling of the warhead, beginning with assembly of the cluster and following through to attachment and checkout of the warhead on the missile.

Having established the warhead concept there were certain problems which must be resolved either by design or by test, or by both. The cluster adapter must be designed to conform to the space available in the nose; and the nose, in turn, would have to provide a suitable method for mounting and retaining the assembled cluster. This was a matter of logical design and coordination.

An entirely new method for positive separation and opening of the warhead would be required. This could also be worked out in the design phases and proved by static and flight tests.

Fuzing is also a design problem which requires integration with the over-all system to insure reliable performance. Success of the fuze development would also have to be established by static and flight tests.

Design of the support equipment appeared to be routine with no particular problems involved. These items would be modified and improved where revisions become apparent through usage.

Apart from the mechanical problems involved there are those which are related to the unit munition, such as ability to reproduce the ballistics of the warhead, ability of the munition to withstand release at velocities from Mach 0.9 to 1.2, determination of the optimum warhead-opening altitude, and the area coverage attainable with this warhead concept. Answers to the questions posed by these problems will be found in the results of the flight test program.

Storage capability of the warhead cluster can only be determined after a comprehensive long-range program, although a reasonable prediction may be made on the basis of knowledge already available on the unit munition.

Based on the allowable warhead weight, a cursory examination indicates that roughly 330 unit munitions can be carried. This agent payload could cover an estimated 114,000 sq.yd., 80% of which would be covered, within 30 sec. after the bomblets impacted, with a sufficient dosage to cause the death of 50% of the exposed personnel.

The characteristics of the E54R6 bomblet will assuredly exert a strong influence on the over-all ballistics of the warhead system. In still air the E54R6 stabilizes immediately after release and has a vertical trajectory to impact, but still air is rarely encountered. The munition is affected in its fall by each change in force and direction of the wind, which have been determined to be 76 ft. of drift for each 1,000 ft. of altitude and each 10 m.p.h. of wind. The average effect, or ballistic wind, can be determined from the meteorological data at any given time and successfully used to calculate the total angular and linear drift of the munition. These effects will have to be taken into account in establishing the missile flight plan by utilizing the best meteorological information obtainable at the target and correcting the missile dump point accordingly. Lack of reliable target information will result in inaccuracy and ineffectiveness of the weapons system.

The principal unknown quantity in the warhead concept is the area coverage which can actually be achieved with the E54R6 munition when the munition is dispersed in such large numbers. It has previously been determined from tests of bomber-borne clusters that the pattern size cannot be increased by any further increase in the opening altitude above a certain point. The questions then are: (1) What area coverage can actually be achieved? (2) At what altitude must the warhead be opened to achieve this area? If the area obtained from the flight tests is approximately equal to that of the theoretical coverage, then it can be said that the military characteristics have been met with a relatively inexpensive, uncomplicated warhead system. However, if the theoretical area coverage is greater than the actual area coverage, then the decision has to be made as to what the minimum acceptable coverage must be to justify the missile expenditure.

2. Establishment of Basic Design.

a. Key Factors.

To meet the military characteristics the key factors are: the payload considerations as defined by the center of gravity, the allowable weight in the nose casing, and the available volume.

These three factors are established by the missile designer and cannot be arbitrarily changed in order to suit the design of the warhead. The center of gravity and allowable weight are flexible to a degree, but the available volume is fixed by aerodynamic considerations. These considerations set definite limits within which the physical characteristics of the warhead must fall in order that the missile-warhead combination will be compatible.

b. Estimation of Area Coverage Desired.

The theoretical area coverage to be attained with a toxic cluster-type warhead will be governed by the following design parameters of the individual bomblets: (1) the dissemination characteristics, (2) the number, and (3) the distribution. The other dominant parameters are: (1) the meteorological conditions, (2) the lethal dosage of the dispersed agent, (3) the criterion in terms of time of dosage-area achievement assumed, and (4) the percent coverage of the area to be attained.

Thus, in the final analysis, from a design viewpoint the first step is to determine how many bomblets can be packaged within the space and weight limitations of the warhead compartment. Once this information is available, the other data are combined, and estimates of the desired distribution of bomblets can be calculated.

For the purpose of estimating the effective area coverage, it was assumed that the bomblets would be distributed over 80% of the area and that 50% casualties would be attained if a dosage of 100 mg.min./$m.^3$ was established in 30 sec. or less from the time of impact of the bomblets.

c. Cluster Adapter.

Based upon the number of unit munitions which can be carried, a design for an adapter to contain these munitions will be required. The physical characteristics of the adapter are governed not only by the number of munitions, but also by the design features of the missile airframe, its aerodynamic configuration, and missile weight and balance considerations. Accordingly, the number of unit munitions and the design of the cluster adapter are directly related to the missile characteristics.

d. Gas Cluster.

The unit munitions and the adapter in combination constitute the gas cluster to be carried by the missile. In developing the design for the cluster and its components, careful consideration should be given to several important factors. They are:

1. Simplicity of design
2. Use of noncritical materials
3. Ease of assembly
4. Ease of handling
5. Safety in assembly, handling, and storage

e. Nose Casing.

Design of the nose casing (or warhead compartment), as an integral part of the missile airframe, is the responsibility of the prime missile contractor. Close coordination and cooperation between the contractor and these Laboratories are essential if an adequate design is to be achieved. Preliminary designs of the nose casing and the cluster adapter are checked against each other and modified where necessary to eliminate any possible mechanical conflict. Considerable thought must be given to the nose casing design which is to result in a warhead compartment capable of transporting the cluster to the target under all design loads, and yet of opening readily and easily over the target without damage to the cluster.

f. Fuzing.

A reliable fuzing system is required to cause the warhead to function at the proper altitude over the target. The fuze system selected will be powered by the missile electrical system and actuated by the missile guidance system. The fuze system will also require certain safe features unique to missiles in general, because arming and functioning are accomplished remotely, either by timing or by impulses received by the guidance sytem. The system will also have to be safe throughout all ground handling operations, through launch, and then beyond to a point where an armed warhead will present no hazard to personnel and materiel within the bounds of friendly territory. It must also be protected against enemy countermeasures.

g. Handling Equipment.

As the development of CW warheads for guided missiles is an entirely new branch of the art, there is little opportunity for employing conventional methods of handling and assembly such as exist for munitions carried by piloted aircraft. Primarily this results from the considerable increase in size and weight of the package carried by the missile, meaning, in this warhead, a threefold increase in weight alone over the largest chemical munition carried in a conventional bomb bay.

To minimize the logistic requirements for the tactical MATADOR missile, every effort should be made to standardize and utilize the equipment required to handle all of the warheads being developed for the missile. This will require close coordination with the other warhead agencies to insure that items of equipment are not needlessly duplicated.

h. Shipping Container.

The size and weight of the payload suggests that shipping rings and guards as used on bomb-bay munitions will not be adequate in the case of the gas cluster for the MATADOR. Hermetic sealing of clusters in the 1,000-lb. range proved difficult enough and may be virtually impossible from a practical standpoint in the case of units of the 3,000-lb. category, and beyond. The loads imposed by normal handling and transportation of these heavy units would require a ruggedness that would impose an unacceptable penalty on the effective-weight of the payload. Therefore, employment of a reusable, hermetically sealed container, with suitable load-dampening devices, is considered the method which will allow for extreme simplicity of design and maximum agent-weight ratio in the cluster.

IV. DEVELOPMENT.

A. Design of Prototype.

The whole problem of developing a chemical warhead for the MATADOR is related entirely to the maximum permissible payload which can be carried by the missile, the location of the payload, and the space available for the payload. These limits are well defined for the B-61A missile inasmuch as the configuration, as well as all other design criteria, has been fixed by the prime missile contractor in accordance with the scope of the contract. These limits impose certain restrictions on the warhead development and may not permit the development of the optimum CW warhead for the missile.

Weight of the warhead including the nose casing ranged from 3,150 lb. for a missile gross weight of 13,215 lb. to 3,350 lb. for a missing gross weight of 13,415 lb., for a constant missile center-of-gravity of 235.8. By design the nose casing alone weighed 220 lb., making a cluster weight ranging from 2,930 to 3.130 pounds. The nose center-of-gravity through this range is 71 to 80 in.

Examination of the available space in the nose section indicated that a maximum of 330 E54R6 munitions could be carried. This quantity of bombs weighs 2,739 lb., leaving only 191 lb. for the weight of adapter and other necessary components, for warhead weight of 3,150 lb. This value represents the forward center-of-gravity limit, i.e., 71 in., and this condition probably would not occur; however, it is a condition which exists and must be reckoned with.

The 330 units were laid out in an arrangement of 6 banks, each bank of which would be included within a circle 32 in. in diameter, which was estimated as the maximum dimension allowable at the forward nose station. The six banks came within the 78 in. available from the forward nose station to the base. Here again it was apparent that the 55 bombs in the bank permitted no weight allowance for the development of an adapter to contain the bombs. Further study showed that by merely eliminating four bombs in each bank, the adapter could be developed with ample allowance for subsequent design changes. This also reduced the bomb weight to 2,540 lb. and increased to 390 lb. the weight available for the adapter and other components.

Based on the new value of 306 E54R6 munitions, the potentiality of the gas warhead was estimated to be 106,00 sq.yd. This area is based on munition expenditure rate of 28.9 bombs per 10,000 sq. yd. in a Gaussian distribution 80% of which area is covered with a lethal concentration (100 mg. min./cu.m.) within 30 sec. ("Munition Expenditure Estimates for the E101R3 Cluster," dated 17 January 1953, prepared by Test Division, C&RL).

The same number of E54R6 bombs in a random distribution potentially is capable of covering an area of 201,000 sq.yd., 80% of which with an equivalent dosage, at a munition expenditure rate of only 15.2 bombs per 10,000 sq.yd. This type of distribution is not possible with the E54R6 munition when the warhead system relies solely on aerodynamic factors for dispersion and can only be achieved by incorporating special mechanical devices in the warhead. In the absence of such a device the former values must be considered for the B-61A warhead.

The foregoing values for area coverage for both Gaussian and random distribution are based on meteorological conditions of slight lapse to extreme inversion, 3- to 8-m.p.h. surface winds, and an air temperature at 50°F. or higher.

A summary of preceding analysis follows:

Table 2

Summary of Design Data on Eb Warhead for MATADOR Missile

	Warhead center-of-gravity	
	70.25 in.	80.0 in.
Gross missile weight	13,215 lb.	13,415 lb.
Warhead weight	3,150 lb.	3,350 lb.
Nose casing weight	220 lb.	220 lb.
No. of munitions	306	306
Weight of munitions	2,540 lb.	2,540 lb.
Missile center-of-gravity	235.8 in.	235.8 in.
Adapter weight	390 lb. (max.)	390 lb. (max.)
Area coverage	106,000 sq.yd	106,000 sq.yd.

From this point the design and development of the warhead and its related components went forward and is reported in detail in the following sections.

1. Weapons System.

a. Nose Case.

Experience gained in the development of chemical warheads for the interim (YSSM-A-1 or YB-61) missile demonstrated the difficulty of designing around a fixed warhead compartment, i.e., establishing the configuration and structural design of the YB-61 nose with no serious consideration for the stowage of the chemical warhead. For example, the space available in the YB-61 nose allowed for no more than 275 E54R6 bombs. By changing the ogive of the nose only slightly it was then possible to contain 306 bombs as in the B-61A nose. The effectiveness of the warhead was seriously hampered by this inflexibility, and the Air Force was requested to authorize that the design of the B-61A warhead compartment and the chemical warhead package should proceed simultaneously with a high-degree of coordination between the Chemical Corps and the prime contractor, the Glenn L. Martin Company. The Air Force agreed to this, and a series of meetings was held with project personnel of the Glenn L. Martin Company.

Preliminary nose-section designs were prepared by The Glenn L. Martin Company, offering seven methods of mounting the cluster. These investigations are reported in detail in Glenn L. Martin Co. Engineering Report 4540 (1). As indicated in this report one design was considered over the others and was eventually brought to its present state through continuous coordination between Chemical and Radiological Laboratories and the Glenn L. Martin Company.

The present B-61A chemical-warhead nose shell is of the split-frame, monocoque design. The entire skin is made of 0.072-in. 24S-T4 clad aluminum alloy sheet from station 40 to 120, and is joined together at the two vertical seams by a splice strap of 0.051-in. 24S-T4 clad aluminum alloy sheet. The frames are made of 0.064-in. and 0.072-in 14S-T6 clad aluminum alloy sheet and are split at each vertical seam. A conically shaped fiber-glass nose is attached to the rib at station 40. Provisions are made for the primacord at both vertical seams by means of a rubber extrusion cemented to a bent-up aluminum alloy angle. The same rubber extrusion was installed around the fiberglass nose just forward of station 40.

The nose shell is attached to the missile center section by means of four high-strength special bolts, heat-treated to 180,000 p.s.i. These bolts are specially designed to contain a commercial du Pont E81 electric blasting cap within a drilled-out portion. The bolt is undercut precisely at the splice station to insure that when the cap is exploded the bolt will shear properly and separate the warhead cleanly from the missile. The bolt is inserted through a recessed "bathtub" fitting in the center section and threaded into a Rosan insert in the longeron in the nose section.

The explosive bolt was the result of an extensive investigation conducted by the Glenn L. Martin Co. with the object of determining the optimum bolt-rupturing charge and the depth of undercut necessary to obtain a clean fracture. The results of some of the experimental work are shown in figs. 2 and 3. The bolt subsequently

FIGURE 2

TEST OF EXPLOSIVE BOLT IN SIMULATED BULKHEAD SHOWING CLEAN FRACTURE USING 15-GRAIN PETN ELECTRIC BLASTING CAP

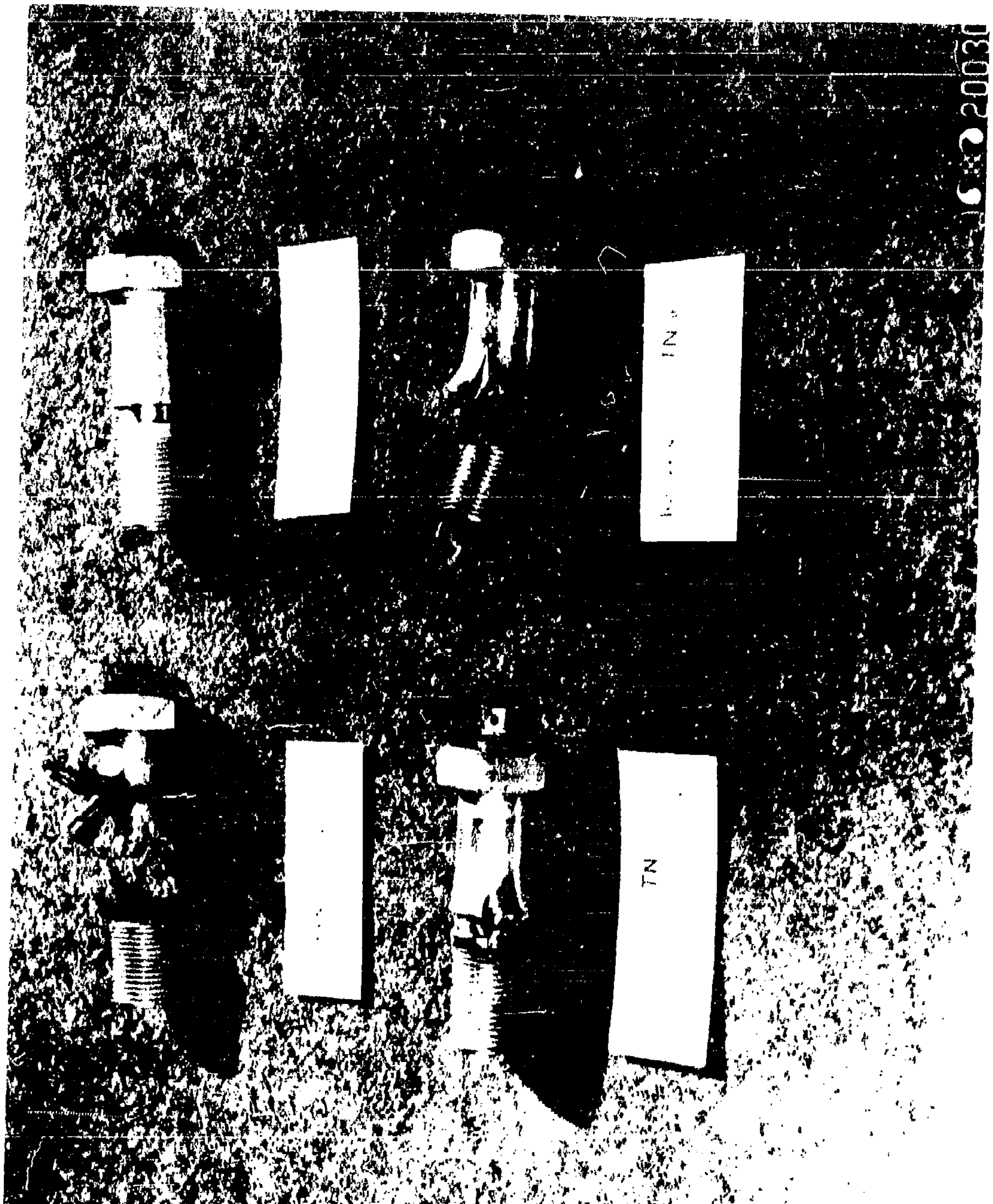

FIGURE 3

TESTS CONDUCTED TO DETERMINE OPTIMUM CHARGE REQUIRED TO FRACTURE EXPLOSIVE BOLT selected was 0.625 in. in diameter; a 0.281-in. hole was drilled from the head through the shank to a depth of 1.625 in. The undercut in the shank is 0.545 in. in diameter and 3/16 in. wide.*

The cluster is supported internally at the forward end by a ring frame nesting the cluster completely around its periphery. At the base the cluster is supported by an X-frame, a circular flanged pan with cross members that attach to the four longerons. The attachment of the cross members to the longerons is accomplished in such a manner that the X-frame is locked in positively until the primacord cuts the nose casing, which immediately frees the X-frame from the base of the cluster.

The nose design was proved by a series of tests. The Glenn L. Martin Co. was awarded a contract (DA-18-108-CML-3462) to fabricate and statically test three B-61A chemical warhead nose casings. By means of the four explosive bolts the noses were secured in a vertical, nose-down attitude to a specially constructed test stand. A lanyard was attached between the base of the nose and a microswitch, which had been mounted on a stationary panel on the test stand to provide a short delay between bolt and primacord detonation. In each test an empty E54 cluster adapter was assembled in the nose. High-speed cameras were placed to film the test from two points, roughly 90° apart.

The tests were conducted successfully with the system functioning in each case as planned. The high-speed movies also indicated that the gases generated by the primacord forced the separation of the nose halves in a very forceful manner. This fact indicated that there would be no interference from the missile nose parts during opening of the cluster. Examination of the adapter showed a series of pock marks in a line directly under the primacord on both sides; otherwise there was no indication of any damaging effect from the blast which might prove harmful to the small munitions. These tests are reported in detail in Glenn L. Martin Co. Engineering Report 5387, including one reel of 16-mm. movie film of the test (2).

In the course of the development of the B-61A missile, an attempt was made to design a universal warhead compartment which could accommodate any of the proposed warheads. Although such a compartment would be very desirable, the idea proved to be highly impractical from several viewpoints; for example, the present configuration for chemical

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*This bolt was eventually redesigned to reduce the diameter to that of the bolt used to attach the primary warhead to the missile, thus permitting use of the same splice fittings and furthering the effort to standardize the missile design.

warheads is much simpler and less costly than that required for the special warhead. An alternate to this proposal would be to design a missile which, from station 120 aft, would be capable of carrying all warheads and also fulfill the needs of any given warhead. This approach would mean considerable simplification from a production standpoint and from a logistic angle.

This principle was adopted in theory; however, in designing the chemical nose which was used on the fin-stabilized warhead this concept was not followed to the letter. The attachment bolts of the original design were a size larger than that used for other warheads; the electrical wiring for the explosive bolts was contained in the missile center section. This arrangement was changed by placing the wiring in the nose casing, and the bolt size was also reduced to conform to that of the other warheads. In addition, the Rosan insert was eliminated by redesigning the nose case longerons to incorporate "bathtub" fittings, as on the center section. The bolt itself was lengthened by 5/8 in., and an elastic stop nut was used in place of the Rosan insert. This modification further simplified the warhead assembly by allowing the use of standard tools and also by making the alignment of missile and warhead less critical during the operation of the bolt attachment. These modifications were built into three noses which had originally been programmed for missile flights with the E125 gas warhead.

b. E54 Cluster Adapter.

Design of the cluster adapter proceeded from the parameters previously described. Here again, the experience gained on the YSSM-A-1 program proved of great value because several undesirable features had already been brought to light so that a sounder approach to the new design was possible. The first consideration was the reduction of weight. The "Y" adapter of the earlier design was of sheet steel construction with unwieldy end plates, which weighed approximately 450 lb. Nevertheless, the adapter was not considered strong enough to withstand handling and shipping.

The field of low-pressure, fiberglass-reinforced plastics was first investigated from weight/strength and availability standpoints. It was indicated that this material could apparently be utilized in the design of the adapter, and design studies were made based on this material. A preliminary drawing was prepared of a design for a cluster adapter molded entirely of fiberglass-reinforced plastic, consisting of two identical halves with the longitudinal axis lying in the parting plane. The two halves of the device are locked together by a latching mechanism running along the edges; the latches, six on each side, being actuated simultaneously by push-pull rods which protrude through the base of the adapter. This latch mechanism is included only to keep the cluster intact during storage, shipping, and assembly in the warhead. After the cluster is assembled in the warhead, the latches are released, and the integrity of the cluster is maintained solely by the nose structure. With the exception of the latching mechanism, the adapter half is molded in one piece.

The preliminary design was submitted to several concerns with invitations to bid on a contract for the design, development, and fabrication of fifty cluster adapters. The Winner Manufacturing Co. of Trenton, New Jersey, was the successful bidder, and contract DA-18-108-CML-3040 was signed on 21 December 1951.

The problem was studied by Winner on the basis of the preliminary design; a preliminary stress analysis indicated that the design was sound and that a comfortable margin of safety existed. Additional latches were incorporated to insure the integrity of the assembled cluster, and locating pins were incorporated at the four corners to facilitate alignment of the two halves. Otherwise, the basic design remained unchanged. A complete history of the development, analysis, and fabrication of the cluster adapter can be found in the contract reports (3). The adapter was subsequently designated Adapter, 3000-lb. Cluster, E54.

The first three adapters were fabricated with 1/4-in. end sections, which failed readily in end-drop tests. The design was changed to increase the thickness to 1/2 in. and the inside radius at the joint between the cylinder and the end was increased. This change proved satisfactory so that no further changes were incorporated in the remaining adapters fabricated. Testing lagged behind fabrication, a condition which made it necessary to accept the remaining adapters on the strength of visual inspection and limited static tests. Despite this gap between manufacturing and testing, subsequent tests revealed only minor defects which could be improved. These items will be noted in detail in the section on flight testing (see p. 58).

Specimens were taken from one of the E54 adapters to evaluate the physical properties of the laminated fiberglass material. All specimens were conditioned for a minimum of 48 hr. prior to test in an atmosphere of 75 ± 2°F. and a relative humidity of 50 ± 2%. These conditions were also maintained during the test. The results are given in table 3.

The values obtained from these tests are in close agreement with the criteria established by Owens-Corning Fiberglass Corporation, makers of the fiberglass mat used in the E54 adapter.

Several samples of the laminated fiberglass were subjected to chemical tests to determine the compatibility of the laminate with GB. Samples measuring 2 by 3/4 by 1/2 in. were cut from the end bulkhead of the E54 adapter. One 2 by 3/4-in. surface was the external face coated with the overlay; the other 2 by 3/4-in. surface was the internal face with no overlay. The other four surfaces were cut through the laminations exposing the fiberglass ends, resin, and filler. Laminate samples were partially immersed in stabilized GB in steel test cups, leaving a 50% void. The cups were closed with bushings fitted with pressure gages and were then stored at 71°C. until removal became necessary due to excessive pressure development. Results of the storage tests are given in table 4.

Table 3

Physical Properties of Laminated Fiberglass Used in the E54 Cluster Adapter

A. Tensile Strength (Fed. Spec. L-P-406b, 1011).

	Restricted Area Width	Restricted Area Thickness	Load	Elongation	Ultimate strength	Remarks
	in.	in.	lb.	in.	p.s.i.	
Average	0.503	0.740	6,887	0.054	18,500	Rate of head travel constant at 0.20 in./min.; five specimens in all
Low	0.495	0.734	5,435	Negligible	14,700	
High	0.507	0.746	8,300	0.063	22,700	

B. Flexural Properties (Fed. Spec. L-P-406b, 1031.1).

Value	Depth	Width	Span	Ratio: span/depth	Load	Maximum fiber stress	Remarks
	in.	in.	in.		lb.	p.s.i.	
Group I: Five Specimens Loaded Parallel to Lamination							
Average	0.385	0.382	6.539	17/1	170.4	29,600	Rate of head travel for both groups constant at 0.10 in./min.
Low	0.381	0.375	6.477	17/1	165.5	28,200	
High	0.388	0.390	6.600	17/1	177.0	30,800	
Group II: Five Specimens Loaded Perpendicular to Laminations							
Average	0.381	0.387	6.485	17/1	176.5	30,500	Rate of head travel for both groups constant at 0.10 in./min.
Low	0.375	0.381	6.375	17/1	162.5	28,900	
High	0.388	0.398	6.600	17/1	191.5	31,900	

C. Compressive Strength (ASTM D695-49T).

	Depth	Width	Thickness	Area	Load at failure	Compressive strength	Compression at failure	Remarks
	in.	in.	in.	sq.in.	lb.	p.s.i.	%	
Average	0.999	0.472	0.499	0.236	5,159	21,900	2.2	Rate of head travel constant at 0.20 in./min.; six specimens
Low	0.998	0.470	0.496	0.235	4,750	20,000	1.5	
High	1.000	0.475	0.500	0.236	5,635	23,900	2.5	

D. Shear Strength (ASTM D732-46).

	Depth	Diameter of shear tool	Area	Load	Shear strength	Remarks
	in.	in.	sq.in.	p.s.i.	p.s.i.	
Average	0.491	1.000	1.541	24,000	15,800	Six specimens, each approximately 2 in. square
Low	0.477	1.000	1.499	23,100	14,800	
High	0.495	1.000	1.558	25,500	16,300	

Table 4

Results of Storage Tests of Laminated Fiberglass in GB

	Specimen 1	Specimen 2	Specimen 3
Length of storage, da.	30	17	30
Pressure developed, p.s.i.g.	82	110	95
Conditions after storage:			
GB recovery, %	77	88	90
GB analysis:			
Acidity, mg.H^+/100 g.	71	63	59
Ionic fluorine, %	1.2	2.4	0.8
Purity, %	61	-	-
Appearance	Cloudy amber liquid; dark deposit on sides and bottom of cup	Amber liquid; black deposit on sides and bottom of cup	Cloudy amber liquid; dark deposit on sides and bottom of cup

The samples presented the same appearance upon removal from storage. All were quite badly damaged: The overlay was flaking off; white growths had appeared on the cut edges; and the specimens were badly swollen.

In examination of the results, i would appear that the laminate is unsatisfactory for use with GB. Although the overlay appears to have been affected by the GB, the principle difficulty was undoubtedly caused by the calcium carbonate base filler used in manufacture of the laminate.

Because of the failure of the calcium carbonate filler, it was decided to investigate the compatibility of GB with other fillers. One that appeared likely to be stable in GB was Columbia Hi-Sil, a silicon dioxide pigment produced by Columbia Chemicals Division of the Pittsburgh Plate Glass Co. Mixtures of 0.050 g. of Columbia Hi-Sil and 30.0 g. of plant-stabilized GB were stored for 1, 2, and 3 mo. at 71°C. in steel test cups equipped with pressure gages. A control test was run on the agent alone.

Results of these elevated-temperature storage tests show that Columbia Hi-Sil has no significant effect on the agent. After 3-mo. storage 20 p.s.i.g. was developed in the mixture of Columbia Hi-Sil and GB as compared with 12 p.s.i.g. for the control. This pressure difference covers the range normally encountered in duplicate tests. It could not be visually ascertained whether the Hi-Sil remained particulate or had dissolved in the agent.

c. Liners.

One feature of the adapter not mentioned heretofore is its capability for carrying any of the existing BW-CW munitions. This is accomplished by interchanging the liners which support the banks of munitions. Development of the liners was originally included in the scope of contract, but later the Winner Manufacturing was relieved of this responsibility, and the development was undertaken in these Laboratories. The prime consideration was selection of a material which would be slightly resilient and yet would not take a permanent set. These characteristics are essential for two reasons: (1) The liner must be resilient to facilitate assembly of the cluster; and (2) the liner must maintain the integrity of the bomb bank under all handling, transportation, storage, and missile flight conditdons for at least 5 yr. without losing its resiliency.

Several materials for liners were studied and either investigated or set aside for future consideration. These materials and the action taken are listed below.

Material and source	Remarks
Royalite U.S. Rubber Co	A lighweight, semirigid synthetic composition, embodying millions of tiny cells which are not connected; although embodying many good characteristics, takes a permanent set from loads in excess of compressive yield stress
Styrofoam Various Sources	A cellular cellulose nitrate composition similar in construction to Royalite; subject to permanent set under excessive loads
Texlite Sponge Rubber Products Co.	Curled hair and/or wool fibers, bonded with sprayed latex; extremely light; appears to have a high moisture-absorption capacity; may be troublesome in forming or cutting to special shapes

Material and source	
Charred cork Armstrong Cork	Charred, shredded cork bonded together in sheet stock; insufficient resilience for this particular application as it has no inherent strength and sections break easily under normal handling; could possibly be employed by applying a coating of latex, but this adds to the production process and considerably increases the cost
Phenolic-filled fiberglass Owens-Corning Fiberglass and others	Material shows great promise, but further investigation was put off due to the time and the initial costs involved; proposed application required that the liners be built up from commercial sheet stock or molded from the raw materials
Spongex Sponge Rubber Products Co.	Made of natural or synthetic rubbers, investigation of this material deferred, pending results of investigation of other materials with a view to finding a satisfactory product which is noncritical or less critical than those utilizing natural or synthetic rubbers as the base
Texfoam Sponge Rubber Products Co.	Product was deferred together with Spongex for the same reasons, being a latex rubber formulation
Rubatex Rubatex Division, Great American Industries	Also a natural or synthetic rubber; set aside with Spongex and Texfoam
Expanded polyvinyl chloride Neff-Perkins Co.	As name implies, this material is formed by expanding molten polyvinyl chloride in molds, using nitrogen gas under pressure; material showed considerable promise and is the one which was investigated most thoroughly; its development as a liner is discussed in greater detail below

The list does not represent all of the materials which had cushioning properties, as others, not named herein, were discarded at sight because of obvious disadvantages.

Expanded polyvinyl chloride, the material most thoroughly investigated, is formed by expanding the molten vinyl with nitrogen gas under very high pressures. The resultant product can be either intercellular or unicellular, dependent on the particular process employed.

In the absence of any specific design information on the expanded vinyls, samples were molded to the exact shape required for a no-load condition in the adapter. These samples were made in these Laboratories at a time when little was known of the processes or characteristics. The average density for this initial lot was about 12 lb./cu.ft., which was a good bit higher than that desired. However, the samples were first tried for suitability in the cluster and appeared to provide firm seating for the munitions. Because of the urgency of the flight test program after a limited investigation of this initial lot, it was decided to produce two complete sets for two clusters; however, production of these two sets of liners consumed an excessive amount of time which could not be tolerated schedule-wise.

Other material sources were then sought, and one manufacturer, Neff-Perkins Co., offered expanded vinyl in sheet form of varying densities and thicknesses. Sheets 2 in. thick having a density of 4.5 lb./cu.ft., from which the liners could be cut, were obtained. The commercial product had several advantages over the laboratory samples, among these being controlled density, unicellular construction, and elimination of the molding process. The laboratory samples had, however, a very high rate of moisture absorption, a condition which was extremely undesirable in this application.

A set of liners for a single bank of bombs was cut with arbitrarily selected outer radial dimensions, and was used to cluster a single bank of bombs in the adapter; deficiencies were noted. The radial dimension was altered until an acceptable fit was obtained. No vibration and shock tests were conducted since they could not be conducted independently of the shipping container, which was also under development.

Samples of the laboratory-produced expanded vinyl were submitted for compatibility tests with GB. The samples were immersed for an extended period of time in stabilized GB in sealed steel cups; they were then removed and examined. They showed no visible evidence of deterioration, but on decontamination they completely disintegrated. It is anticipated that samples of the commercial product will be subjected to the same test to determine whether the cell structure has any bearing on the ability of the material to remain stable during and after immersion in GB. More work is required on the various materials before it can be safely said that the final choice will be completely satisfactory.

d. E125 Nonpersistent-Gas Cluster.

(1) Assembly.

Having procured a quantity of E54 adapters and liners, the next phase concerned the static testing of the E125 gas cluster. Fit tests were conducted utilizing the E54R6 gas bomb. Some difficulty was encountered in the early clustering operations when cork was used as the liner material, as it was virtually impossible to secure the top half of the adapter without applying excessive pressures. This was due primarily to the difficulty encountered in holding any tolerances when cutting the cork and also to the lack of uniformity of the inner surface of the adapter.

When the fit tests were repeated using molded expanded vinyl liners, the clustering operation was accomplished without difficulty, and the top half was installed and locked in place by applying hand pressure only. All of the preliminary clustering operations showed the need for a suitable method of retaining the liners and the munitions which extend above the parting line.

(2) Acceleration Load Tests.

The cluster was next tested to determine its ability to withstand the missile acceleration loads at launch and in flight. The severest load conditions imposed are 5 g axially and 4 g laterally. In considering the axial loads, it is evident that the loads are transmitted through the base of the cluster to the X-frame and thence through the missile structure. The only effect produced is a crushing load on the adapter base, which is well below the limits for the glass laminate.

The lateral loads imposed were carried by the E54 adapter and taken out at each end. This condition required investigation, and a procedure was established for performing the load tests, described in detail as follows:

An E54 adapter half was placed in a supporting fixture which duplicated the method of support in the nose casing (fig. 4). The adapter was partially assembled with 6 banks of E54R6 bombs, having 29 bombs per bank. A reinforced steel plate was placed on each bank as a support for the hydraulic ram and also as a means for distributing the hydraulic load uniformly over the top layers of bombs.

The applied load per bank was determined as follows:

Weight of unit munition, lb.	9.3
Number of munitions per bank (actual)	51
Number of munitions per bank (test)	29

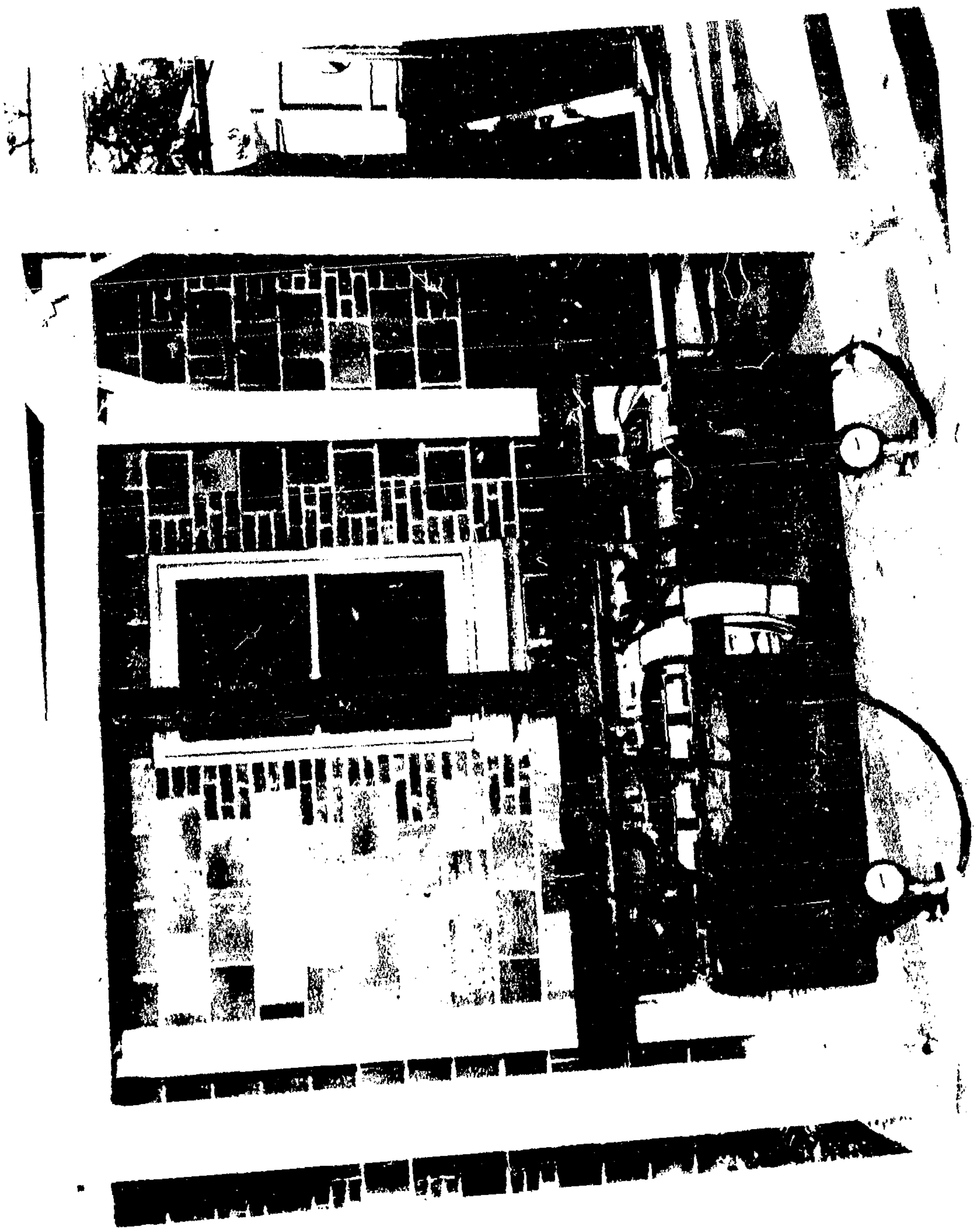


FIGURE 4

STATIC TEST OF LATERAL G LOADING OF E125 CLUSTER (VERTICAL LOADS)

Weight of E54 adapter, lb.	240
Weight of adapter per bank (actual), lb.	40
Weight of adapter per bank (test), lb.	20
Weight of munitions per bank (actual), lb.	474.3
Weight of munitions per bank (test), lb.	269.7
Weight of cluster per bank (actual), lb.	514.3
Weight of cluster per bank (test), lb.	289.7
Acceleration load, g	4
Safety factor	1.15
Duration, sec.	15

Applied load per ram = wt. of cluster per bank (actual) x acceleration load x safety factor - wt. of cluster per bank (test)

$$= 514.3 \times 4 \times 1.15 - 289.7$$

$$= 2365.78 - 289.7$$

$$= 2076.08 \text{ lb. per ram}$$

Note: Weight of the cluster adapter was assumed to be uniformly distributed over its length. Weight of pressure plates and rams was neglected.

An actual load of 2079 lb. was simultaneously applied on each bank for a minimum of 15 sec. Accurate measurements of deflections were not made, but it was evident from the use of a steel straight edge along the sides and the bottom before and after the load application that the deflection was negligible. Moreover, there was no indication of fatigue or cracking.

The effect of the side loads was investigated in a similar manner, except that in this test a complete E54 adapter was used and rotated 90° in the test fixture. As shown in fig. 5, the hydraulic load was transmitted through the adapter by means of two solid steel rods bearing on a reinforced steel plate which rested on the partial bank of bombs. The hydraulic ram was placed on a steel bridge which spanned the two steel rods.

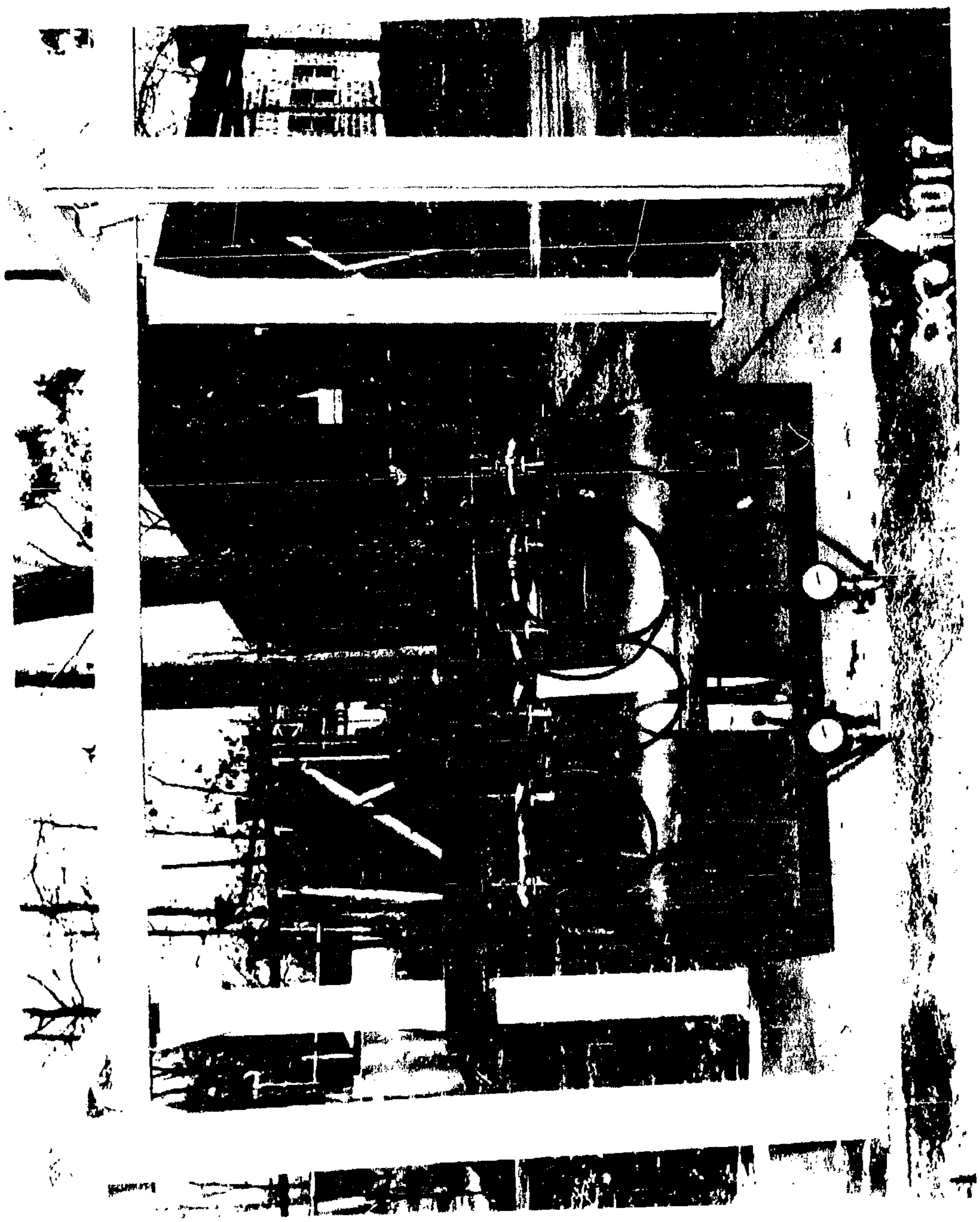


FIGURE 5

STATIC TEST OF LATERAL G LOADING OF E125 CLUSTER
(HORIZONTAL LOADS)

The applied load was determined in the same manner, as follows:

Weight of unit munition, lb.	9.3
Number of munitions per bank (actual)	51
Number of munitions per bank (test)	32
Weight of E54 adapter, lb.	240
Weight of adapter per bank (actual), lb.	40
Weight of adapter per bank (test),	20
Weight of munitions per bank (actual), lb.	474.3
Weight of munitions per bank (test), lb.	297.6
Weight of cluster per bank (actual), lb.	514.3
Weight of cluster per bank (test), lb.	317.6
Acceleration load, g	4
Safety factor	1.15
Duration, sec.	15

Applied load per ram = wt. of cluster per bank (actual) x accelation load x safety factor - wt. of cluster per bank (test)

= 514.3 x 4 x 1.15 - 317.6

= 2365.78 - 317.6

= 2048.18 lb. per ram

The results of applying a load of 2053 lb. for 15 sec. again showed no visible effect on the adapter.

It should be noted that these tests were conducted early in the program; since that time, two factors have changed which, although there was no real effect on the over-all results, could conceivably be critical. In one instance, the weight of the product-type E54R6 bomb was reduced to 8.3 lb.; and in the other, the E54 adapter weight was stabilized at 300 lb., an increase of 60 lb. The net change was a 246-lb. over-all decrease, which results in an increase in the safety margin by a factor of

1.085. Any significant change in the other direction might have resulted in a marginal condition and illustrates the difficulty of designing to close limits when so many other components and factors are subject to change.

The weight limitations imposed by the military characteristics were established early in the missile program when the prime concern was the development of the basic missile, and little attention was paid to the warheads which would eventually be carried. The transition from the YB-61 to the B-61A caused a number of changes in the physical data, which affected the total warhead weight and location of the center-of-gravity. While these changes were significant, the effect on the design of the E6 warhead was negligible in the early phases of the B-61A program; but as time went on, it was found that alignment of the booster rocket was very critical, and it was necessary to tighten the limits on the weight and center-of-gravity of each component. A nomograph (fig. 6) was prepared by the Glenn L. Martin Co., establishing requirements for the warhead weight and center-of-gravity to maintain a constant missile center-of-gravity. On the basis of this nomograph, the E125 cluster was reevaluated and modified to conform to the new limits.

One other factor in establishing the warhead center-of-gravity was the location of the trunnion fittings. For loading and handling purposes, the center-of-gravity should preferably be located aft of the trunnion fittings so that the base of the warhead would tend to rotate downward. This location is in keeping with the design of the warhead-handling equipment, which utilizes a four-point attachment, i.e., the two trunnions and two pickup points, at station 118.375.

The calculations for the weight and center-of-gravity of the E125 cluster are presented as follows:

Symbols:

W - weight

X - distance from nose to c.g. of component

Subscripts:

a - adapter

aa - cluster

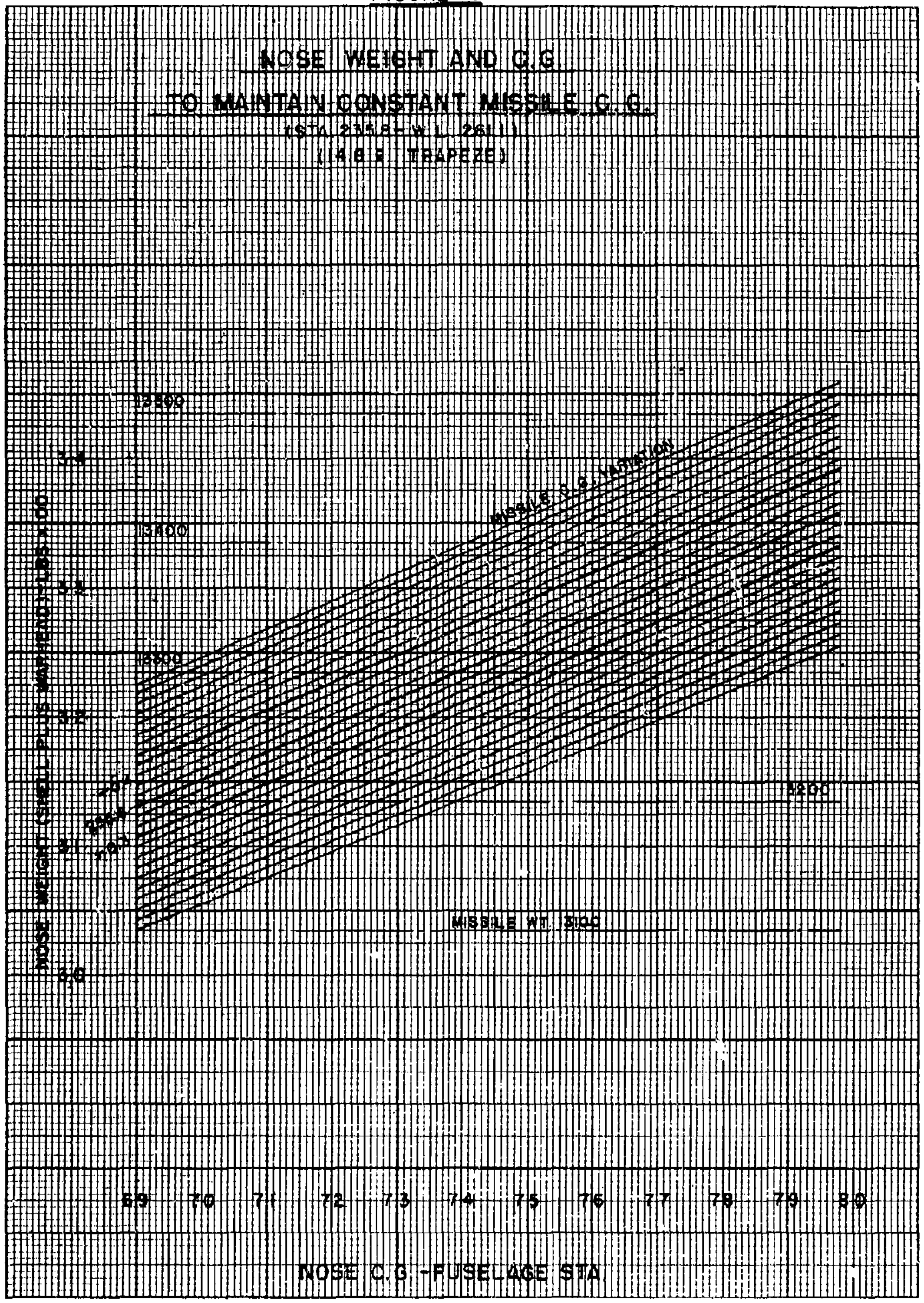
af - afterbody of missile

b - unit bombs

c - nose casing

l - liners

FIGURE 6


NOSE WEIGHT AND C.G.
TO MAINTAIN CONSTANT MISSILE C.G.
MISSILE C.G. VARIATION
13500
13400
3.4
3.3
3.2
3.1
3.0
3200
MISSILE WT. 3100
69
70
71
72
73
74
75
76
77
78
79
80
NOSE C.G.-FUSELAGE STA.

m - complete missile

s - spacers

w - complete warhead

Missile Design Values:

$W_a = 300 \pm 10$ lb. $X_a = 40.5 + 37 = 77.5$ in.

$W_{af} = 10{,}249$ lb. $X_{af} = 286.8$ in.

$W_c = 220$ lb. $X_c = 86.5$ in.

$W_b = 8.3$ lb. $X_m = 235.8 \begin{smallmatrix} +0.3 \\ -0.4 \end{smallmatrix}$ in.

The unit bomb, E54R6, is 12 in. long and 3-5/8 in. in diameter; the center-of-gravity is located 5.844 in. from the nose. Its weight, as noted, is 8.3 lb.

Equations:

$$W_{aa} = W_a + W_b + W_1 + W_s$$

$$W_w = W_c + W_{aa}$$

$$W_m = W_{af} + W_w$$

$$X_{aa} = \frac{W_aX_a + W_bX_b + W_sX_s}{W_{aa}}$$

$$X_w = \frac{W_cX_c + W_{aa}X_{aa}}{W_w}$$

$$X_m = \frac{W_{af}X_{af} + W_wX_w}{W_m}$$

Bomb Loading:

51 bombs/bank x 6 banks x 8.3 lb./bomb = 2,539.8 lb.

51 bombs/bank x 8.3 lb./bomb = 423.3 lb./bank

The trunnions are located at station 76.594, which, for handling safety, is the extreme forward limit of the warhead center-of-gravity. From the nomograph (fig. 6), the warhead weight range at station 76.6 is between 3,255 lb. and 3,315 lb., with the desirable weight set at 3,280 lb. (corresponding to a missile center-of-gravity of 235.8 in.).

$$W_{aa} = W_a + W_b + W_1$$

$$= 300 + 2{,}540 + 25$$

$$W_{aa} = 2{,}865$$

$$W_c + W_{aa} = 220 + 2{,}865 = 3{,}085$$

Ballast required = desired wt. - actual wt.

$$= 3{,}280 - 3{,}085$$

$$= 195 \text{ lb.}$$

A steel plate 1 in. thick, 29 in. in diameter, with two parallel circular segments 27 in. apart cut away, will provide 185 lb. of ballast. The additional 10 lb. of weight will be taken up by the fuze, which has not been included in the weight calculations.

Placing the warhead center-of-gravity at station 77.0 will require a cluster center-of-gravity, as follows:

$$W_w X_w = W_c X_c + W_{aa} X_{aa}$$

$$X_{aa} = \frac{W_w X_w - W_c X_c}{W_{aa}}$$

$$= \frac{(3{,}270)(77.9) - (220)(86.5)}{3{,}050} = \frac{232{,}800}{3{,}050}$$

X = 76.4 in. (35.9 in. when measured from forward face of adapter).

By examination and trial it was determined that the steel spacer, if placed between the second and third bomb banks, would locate the warhead center-of-gravity properly, as evidenced by the following calculations:

$$X_{aa} = W_a X_a + W_b X_b + W_1 X_1 + W_s X_s \text{ or}$$

$$= \frac{(300)(37)+(846.6)(11.844)+(169.32)(48.844)+(8.32)(12.5)+(16.68)(49.5)+(185)(25)}{3{,}050}$$

$$X_{aa} = \frac{11{,}100 + 10{,}050 + 82{,}700 + 104 + 826 + 4{,}625}{3{,}050} = \frac{109{,}405}{3{,}050}$$

X_{aa} = 35.9 in. (76.4 in. in terms of missile station)

As further proof of this value:

$$X_m = \frac{W_{af}X_{af} + W_wX_w}{W_m}$$

$$\text{or} = \frac{(10{,}249)(286.8) + (3{,}270)(77.0)}{13{,}519} = \frac{2{,}940{,}000 + 252{,}000}{13{,}519} = \frac{3{,}192{,}000}{13{,}519}$$

X_m = 235.9 in.

Summarizing:

Wt. of cluster (W_{aa}) = 3,050 lb.

Wt. of warhead (W_w) = 3,270 lb.

Wt. of missile (W_w) = 13,519 lb.

C.g. of cluster (X_{aa}) = sta. 76.4

C.g. of warhead (X_w = sta. 77.0

C.g. of missile (X_m = sta. 235.9

e. Fuze, Mechanical Time, T1404.

With the transition from YSSM-A-1 warhead to the SSM-A-1 or B-61A, the fuze concept underwent radical changes. A new set of military characteristics was prepared at these Laboratories and submitted to Picatinny Arsenal through Office, Chief of Ordnance, with a request for the design, development, and fabrication of 100 units to be used by these Laboratories in conjunction with the test program. These characteristics, modified by Picatinny Arsenal, are as follows (4):

(1) The fuze shall provide two elements governed by a mechanical timing mechanism. One element shall be for the operation of an electrical switch within the fuze (28-v. d.c., 14 amp.) with terminals placed in an accessible location on the outside of the fuze housing. The second element shall be for the initiation of primacord by the use of an M36 electric detonator.

(2) The timing mechanism shall be capable of being set within the range of 5 to 90 sec., in increments of 1/2 sec. for the operation of the switch. The initiation of the primacord shall be delayed 4 ± 1/2 sec. after the set time. If feasible, this delay should be accomplished by

electromechanical means; otherwise, the delay will be accomplished by means of a powder delay element. This powder-train delay element will be provided with an electric primer for initiation, which will be activated by the missile power supply at the same instant the electric switch is closed.

(3) The timing accuracy shall be ± 1 sec. throughout a temperature range of -65°F. to + 125°F. (Note: The desired timing accuracy is ± 1/2 sec. for this temperature range.)

(4) The fuze shall be able to withstand an initial acceleration force of 12 g and function satisfactorily when undergoing an acceleration of 7 g from any direction. The aforementioned g requirements include a safety factor of 1.75.

(5) The fuze shall not be capable of functioning until armed. Fuze to be electrically armed by means of a solenoid and pin arrangement. The energizing of solenoid to be accomplished by missile circuitry.

(6) The fuze shall show evidence of being armed or unarmed by visual external inspection.

(7) The electric detonator shall be physically separated from communication with the primacord when the fuze is in the unarmed condition, so that if the detonator were to function from any cause, the primacord would not be initiated. The fuze shall be so designed that the detonator cannot be assembled in the armed position.

(8) The fuze must remain safe during flight until arming occurs at the prescribed time.

(9) The fuze shall be of a design suitable for mass production.

(10) The metal parts shall be protected against corrosion, as determined by the salt-spray test.

(11) The fuze shall be of minimum size and weight consistent with requirements.

(12) The fuze shall be designed for fabrication from materials which are readily procurable in time of war.

(13) The fuze shall be capable of assembly in the missile after installation of the warhead. Fuze to be mounted by the use of brackets, so designed as to permit setting of the timing mechanism after the fuze is mounted. Mounting dimensions will be coordinated with the missile designer through Picatinny Arsenal.

(14) The fuze shall be capable of withstanding the following development tests:

(a) Temperature and humidity test as described in Specification MIL-Std-304. Consists of cycling fuzes between the extremes of +160°F.(95% r.h.) and -80°F. at beginning, rising to -65°F. during test. Criterion for passing is that fuze must be safe and operable following tests.

(b) Jolt test as described in Specification MIL-Std-300. Test consists of jolting each sample fuze 1,750 times in each of three positions in the jolt-testing machine, as shown on Ordnance Corps drawing 81-3-30. Criteria for passing are that no element shall explode or become unsafe due to parts breaking, becoming deformed, or some similar occurrence.

(c) Transportation vibration test as described in Specification MIL-Std-303. Test consists of vibrating sample fuzes according to a specified schedule of frequencies, amplitudes, and durations. Criteria for passing are that the fuze must be safe and operable following the test. Fuze to be set prior to test. Fuze must function at that setting after test.

(15) The fuze must be of such a design that it can readily be packed in hermetically sealed containers. When packed (in hermetically sealed containers, which are in turn packed in a wood box) the fuze will withstand in any sequence the following tests:

(a) Four 4-ft. drops on a concrete surface, each drop on a different diagonal of the packing case.

(b) The fuze will withstand 96 drops in a standard 14-ft. revolving drum such as is used at Picatinny Arsenal.

(c) Vibration in any direction at a frequency of 550 cycles/min. at an amplitude of 1/4 in., total excursion for 4 hr.

(d) 40-ft. drop test simulating 500-lb. munition dropping onto reinforced-concrete slab.

(e) Standard AMC dust test.

(f) Rain test and freezing test.

The above program was originally proposed as an extension of the T1401 fuze development; but the program called for a fuze which was virtually a new item, later designated the T1404.*

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*Picatinny Arsenal had originally proposed the designation T1401E1, but it soon became evident that the proposed item bore no resemblance to the T1401. Consequently, the new designation was adopted.

In November 1952, Office, Chief of Ordnance reassigned the project to Diamond Ordnance Fuze Laboratories because of the heavy work load being carried by Picatinny Arsenal.

Diamond Ordnance Fuze Laboratories prepared a preliminary design of a fuze and fabricated one model. This design and model formed the basis for a production model which was designed by Raymond Engineering Laboratories. Raymond simplified the logistic and tactical employment of the T1404 fuze by combining two complete units in one package with individual time-setting and arming indicators (figs. 7 and 8). In all respects the production version of the T1404 complies with the military characteristics in so far as the test program has progressed.

Representatives of Diamond Ordnance Fuze Laboratories participated in three tests of fin-stabilized warheads on a "ride-along" basis to determine the functioning characteristics of the fuze. The fuzes were mounted with scratch recorders, which provided a permanent record of the functioning of each circuit and the total time for each event. The time of initiation of each event was also measured on the recording disk. In the first test the recorder showed normal functioning of each phase with the explosive-bolt detonator switches closing at 29 and 30 sec., the manual setting being 30 sec. The primacord detonator circuits were energized 4 sec. later. The only explanation for the timing error of 1 sec. for the detonator switch was a slight maladjustment of the T3 clock, the mechanical timing device.

No results were achieved on the second test due to a malfunction of the primary system, causing the fin-stabilized warhead to land intact. The recorder was damaged beyond any possibility of reading the disk. On the third test the recorder was recovered intact. The explosive-bolt detonator switches closed at 29-1/2 and 30 sec. Again the manual setting was 30 sec. One primacord detonator circuit operated in 34 sec., whereas there was no indication of functioning in the second circuit, the apparent cause of the failure being a defective contact in the rotor circuit.

Diamond Ordnance Fuze Laboratories has successfully conducted a number of tests on the out-of-line safety feature, in which the detonator is fired with the rotor in the out-of-line position. The rotor in this position is 120°, or linearly 0.750 in., out of line and is shielded from the primacord relay by the barrier plate of 0.379-in. aluminum. The barrier plate is also the baseplate of the fuze.

Shock and vibration tests have also been conducted with excellent results. No component failures occurred as a result of these tests.

Further development and testing of the T1404 was curtailed as a result of the Air Force directive canceling all future work on the chemical warheads for the MATADOR.

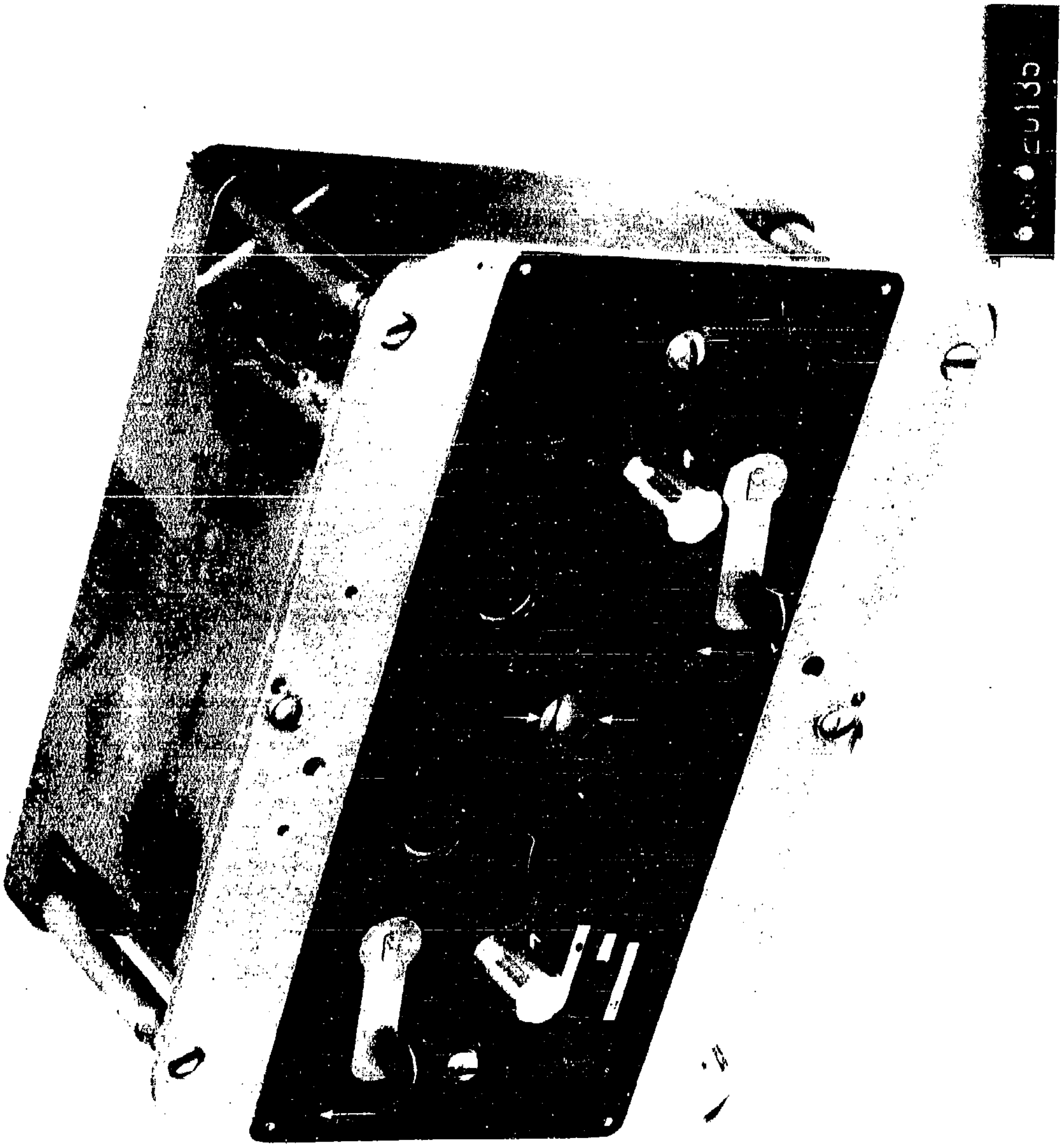

FIGURE 7

EXTERNAL VIEW OF T1404 FUZE

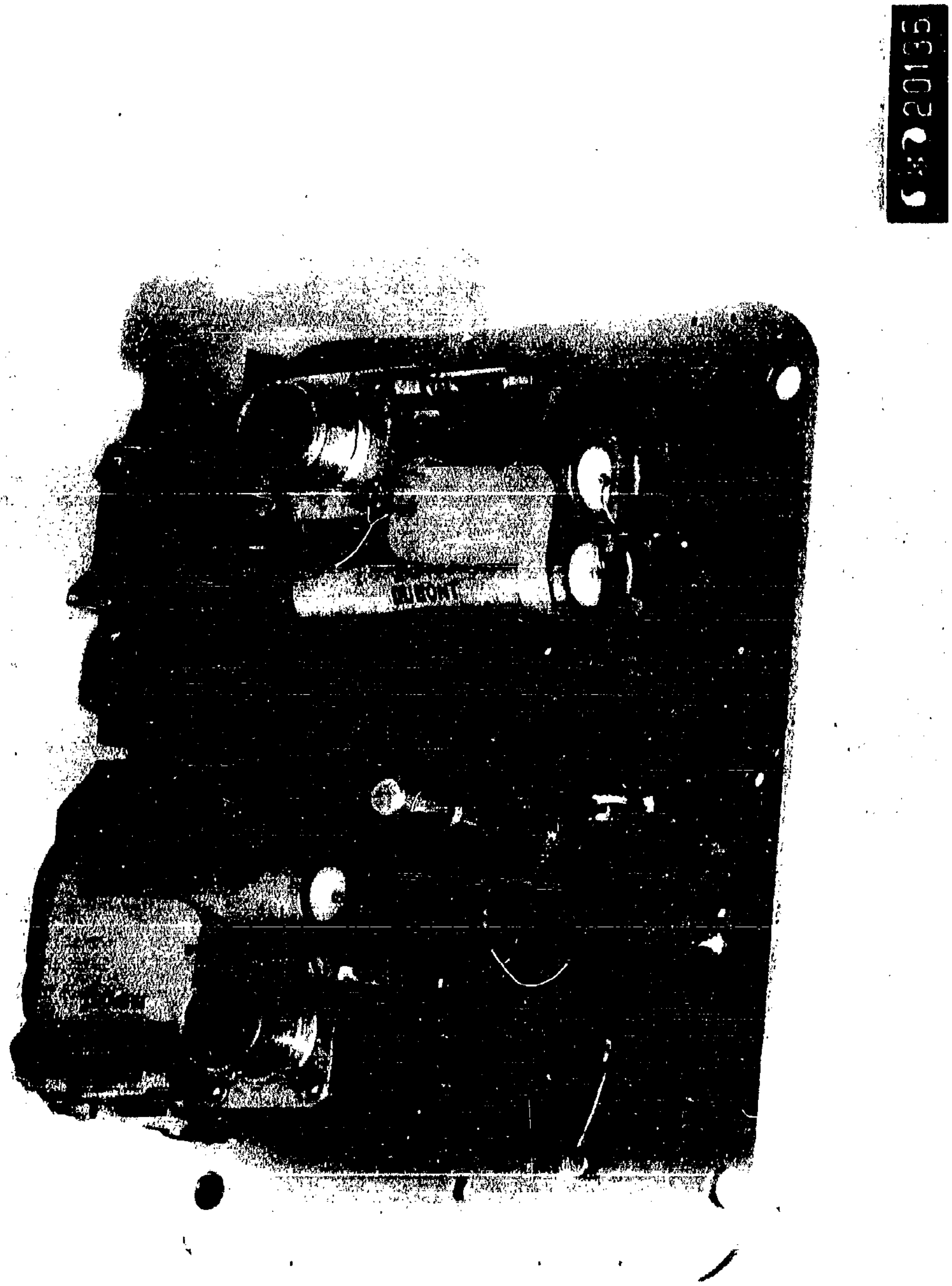

FIGURE 8

INTERIOR VIEW OF T1404 FUZE

f. Interim Fuze.

Development of the T1404 fuze was unavoidably delayed at Picatinny Arsenal because of unsuccessful contract negotiations, so that the program lagged behind the other phases by approximately 1 yr. As the need for an interim fuzing system for the dynamic test program was evident, a program was established to develop a safe and reliable system which could be used until the T1404 became available.

The interim system which resulted consisted of two primary components: an electromechanical timer, fig. 9, and a delay detonator, fig. 10. Fig. 11 shows an exploded view of the electromechanical timer with the mechanical timer shown on the right; the switch housing, center; and the AN 3210-1 microswitch, left. The timer is built around the standard T3 clock, which releases a spring-loaded striker pin at the end of the preset time. The pin strikes the actuator button on the microswitch, thus energizing the circuit and firing the explosive-bolt blasting caps.

The delay detonator, shown in an exploded view in fig. 12, consists of the main barrel which holds the pyrotechnic delay, the booster, the out-of-line detonator, and the primacord holder. The spring-loaded pin shown at the top keeps the detonator out of line until the nose separates from the afterbody. The pin, which has been depressed by the missile afterbody, allows the detonator rotor to swing into line. The delay detonator is energized at the instant the timer switch closes and fires after a 4-sec. delay. The electric squib shown in fig. 12 was replaced later by an electric match, which performs more effectively through the lower temperature range.

A series of tests was conducted on the electromechanical timer and the delay detonator under normal surface conditions in the open. Ten complete systems were tested using a 27-v. battery as the power unit. The timers were each set for a specific time increment and armed manually. Timing was accomplished by stopwatch and appeared to be accurate within human limitations of starting and stopping the watch. (Timing of the units was secondary on these tests.) All of the delay detonators fired successfully.

High-altitude, low-temperature tests were conducted on the interim fuze components to establish their reliability under temperature-pressure conditions which could be expected in the flight test program.

The tests were performed at temperatures of -40° and -65°F. in a vacuum of 23 in. Hg using a 27-v. battery as the power source (see fig. 13). The arming pin on the timer was released by means of a solenoid, which initiated the timing sequence. The timer was set for 32.75 sec., at which time the microswitch closed the electric-squib circuit in the delay detonator. An electric time clock was connected into the circuit and arranged so as to start when the arming pin was pulled and to stop when the microswitch closed the electric-squib circuit. Another electric time clock was used to measure

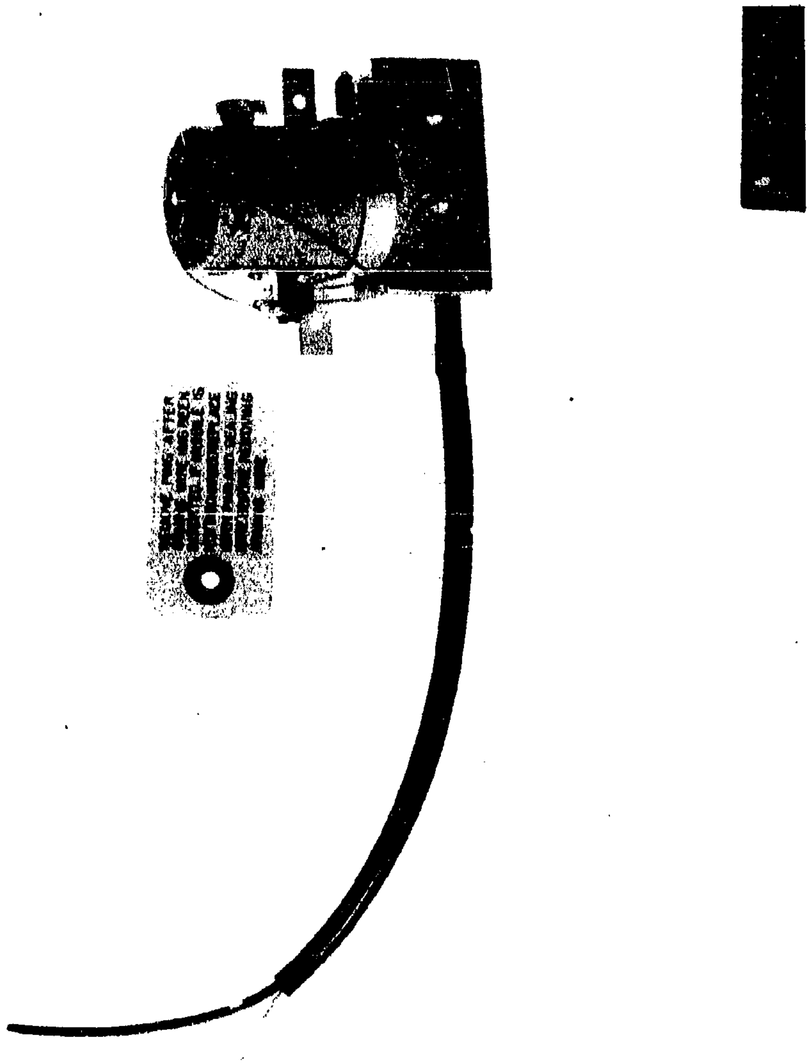

FIGURE 9
INTERIM TIMER ASSEMBLY

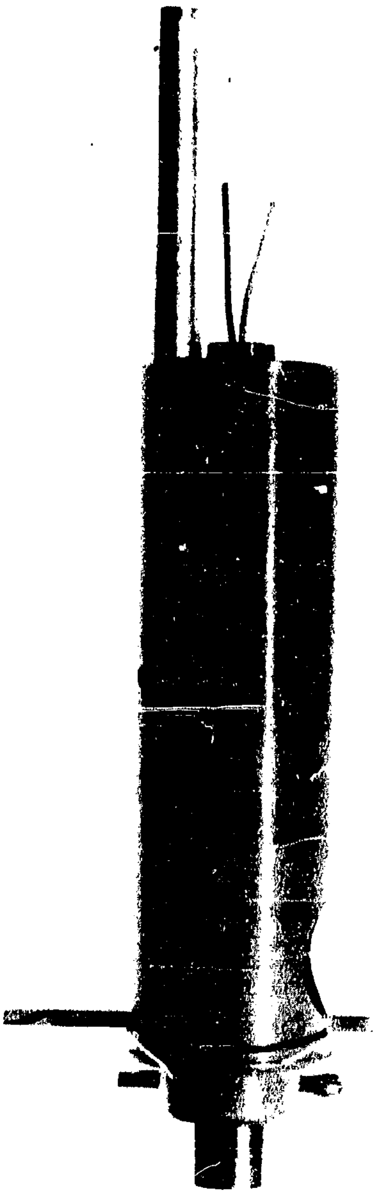

FIGURE 10

DELAY DETONATOR ASSEMBLY

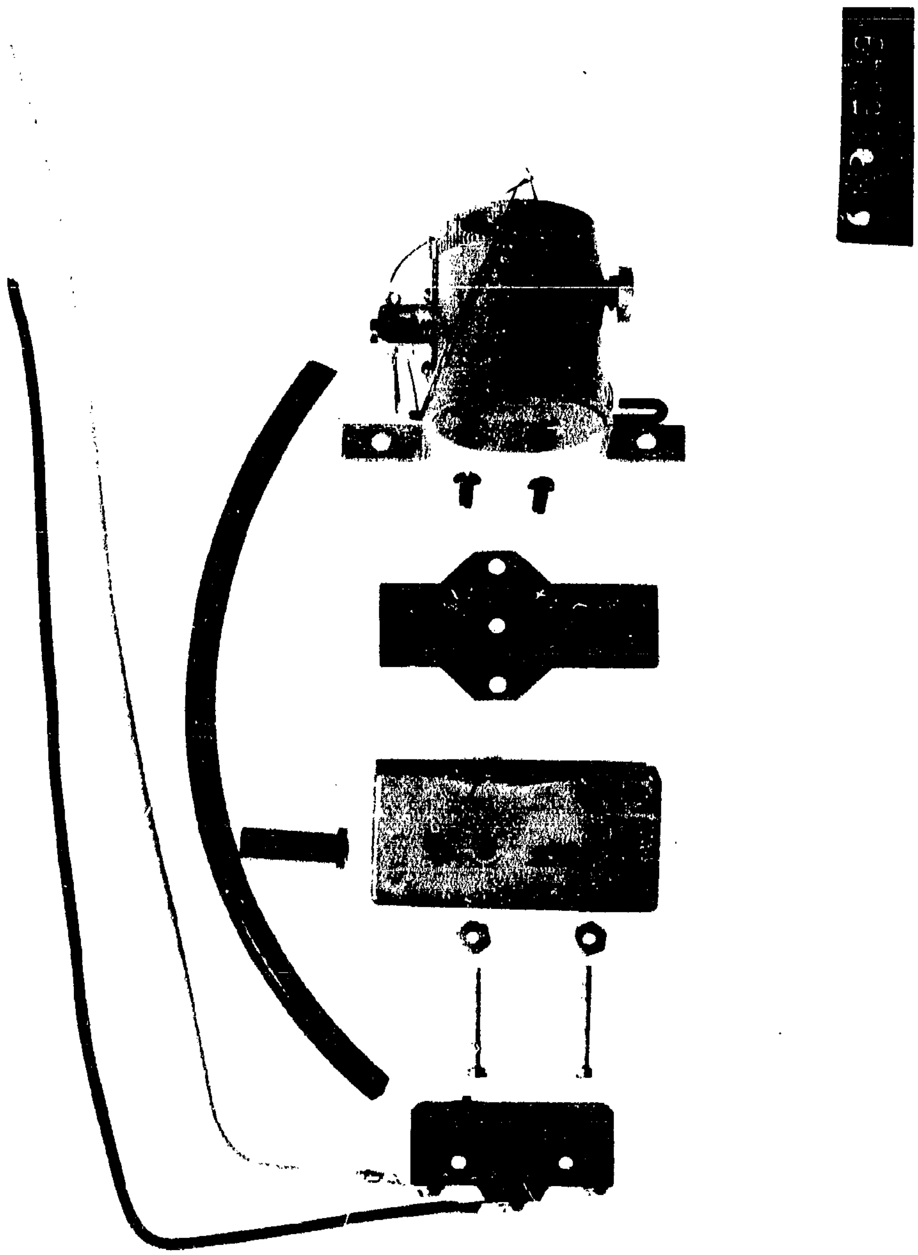

FIGURE 11

EXPLODED VIEW OF INTERIM TIMER ASSEMBLY

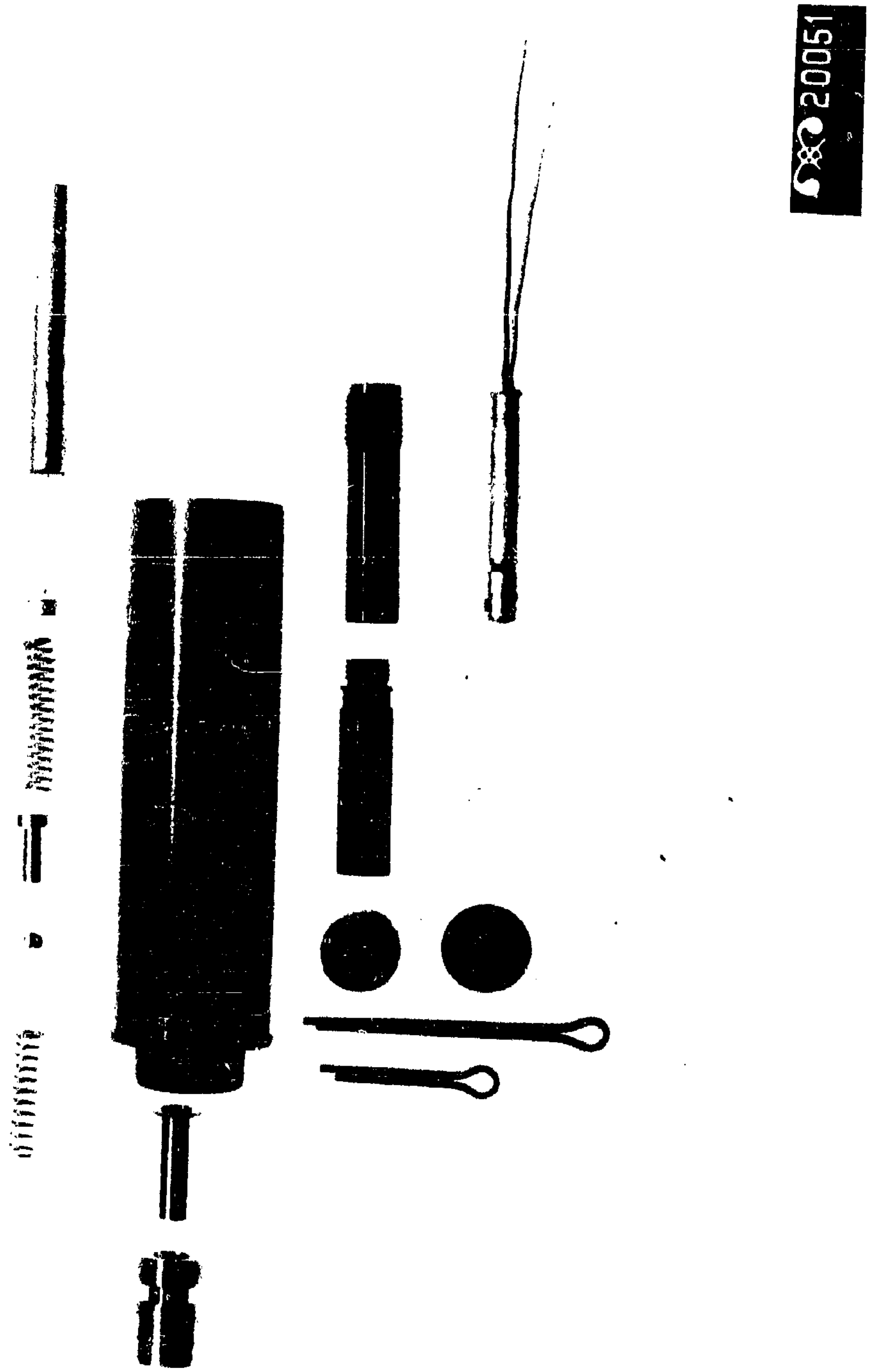

FIGURE 12

EXPLODED VIEW OF DELAY DETONATOR ASSEMBLY

FIGURE 13

A VIEW OF THE DELAY DETONATORS AFTER FUNCTIONING AT -40° AND -65°F.

the total period of time from the start of the electromechanical timer to the time the delay detonator functioned. The differential between the two clocks would then be a measure of the delay period in the delay detonator. The test arrangement mounted in the vacuum chamber is shown in fig. 14.

The first test was conducted at -40°F. with the timer set at 32.75 sec. Clock 1 stopped at 32.75 sec., but clock 2 continued well beyond the predicted firing time before power was cut off. Investigation showed that the first-fire mix in the delay detonator was not intense enough to ignite the tetryl cap or primacord. On the second trial at -40°F. the intensity of the first-fire mix was increased. The timer was set at 32.5 sec., which was the reading obtained on clock 1. Clock 2 stopped at 38.1 sec. for a successful trial. The time differential of 5.6 sec. vs. 4.5 predicted is reasonable for experimentally loaded units.

At -65°F. the timer was inadvertently set at 5.5 sec., which was the time recorded on clock 1. Again the first fire was not intense enough to ignite the tetryl cap. The test was rerun with a more intense mix, with clock 1 stopping at 32.5 sec., the preset time, and clock 2 stopping at 38.1 sec. Time did not permit any further testing to establish the degree of reliability, and it was decided that a calculated risk must be accepted in order to prevent any further delay in flight testing.

2. Support Equipment.

a. Shipping Container.

The matter of storing and shipping the E125 cluster could be handled in one of two ways. One method would be to design the cluster adapter in such a manner that it would serve as its own shipping container. This would entail chiefly hermetically sealing of the cluster adapter and providing shipping guards for protection and ease of handling. Although feasible, this approach would require such additional strength in the adapter as to make the weight prohibitive. Beside the weight consideration, the loss in payload, estimated to be approximately 70 E54R6 bombs, would also be serious enough to reduce the warhead effectiveness considerably. Based on the experience gained in the design of smaller-size clusters (750 and 1,000 lb.) incorporating hermetic sealing, development of a positive seal for a 3,000-lb. unit is felt to be virtually impossible, considering the rough handling to which the cluster will be subjected and also the in-flight vibrations transmitted to the cluster by the missile.

The practical approach is to provide a shipping container which has incorporated in its design the characteristics necessary to insure safe storage and delivery of the munition. A brief survey of the work done in the field of packing and packaging revealed that the use of reusable containers has enjoyed a considerable expansion in recent years.

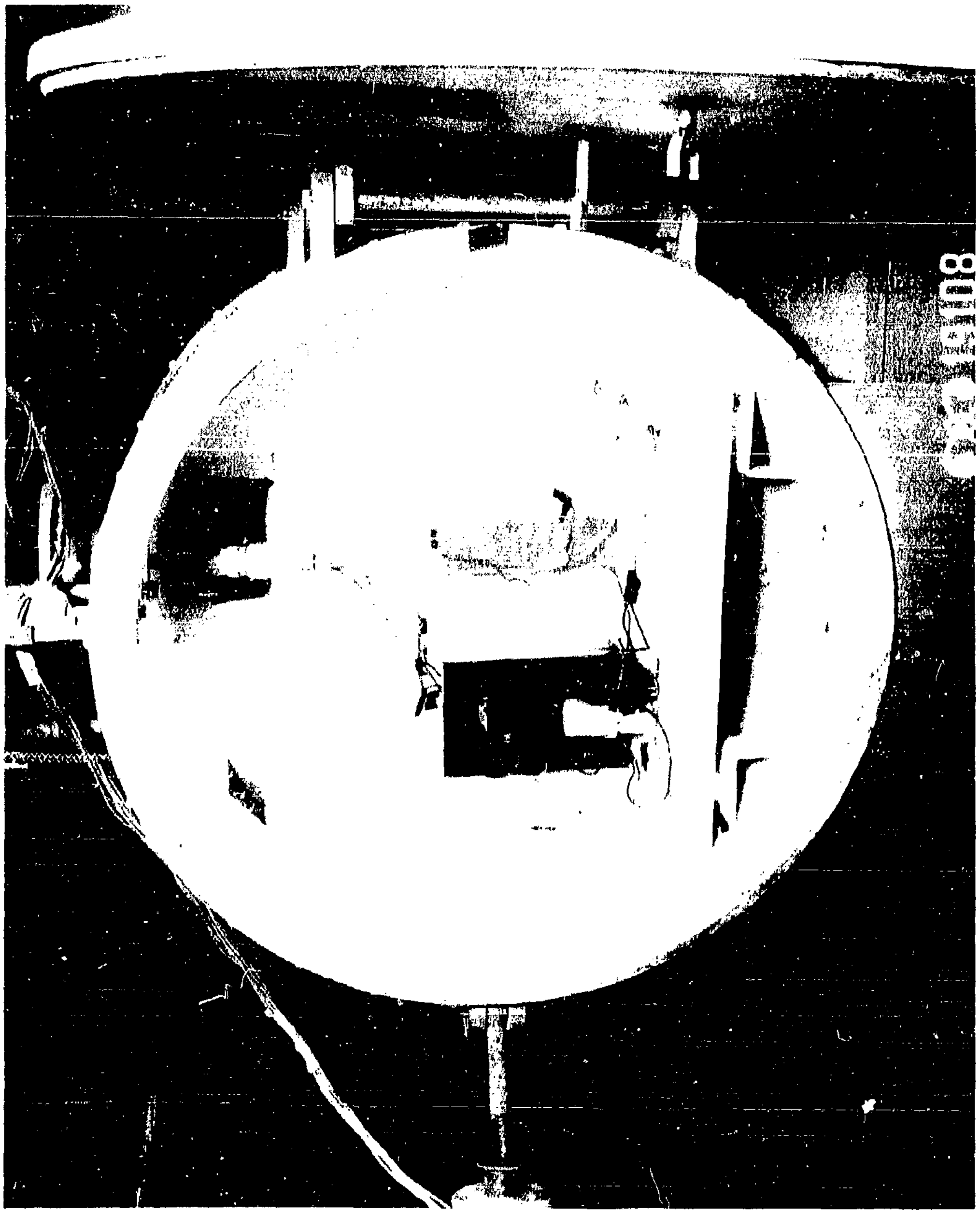

FIGURE 14

TEST SETUP OF ELECTROMECHANICAL-TIMER COMPONENTS BEFORE TEST, SHOWING INSIDE OF VACUUM CHAMBER

All manner of delicate instruments and components have been successfully stored and shipped by all means of transportation in containers utilizing shock-isolation systems. The B-61A itself has a series of seven shipping containers for the seven major components, which provide hermetic sealing, desiccants, and shock isolation, although these packaging requirements were later reduced on all components except on the powerplant and the electronic shelf.

A study of the requirements for a 3,000-lb. cluster container indicated that the problem assumed major aspects and could best be accomplished by having the work performed under contract with a qualified private concern. Accordingly, contract DA-18-108-CML-5109 was awarded to the Universal Moulded Products Corporation for the design and development of ten reusable shipping containers. The following characteristics were established by these Laboratories to guide the development (5).

(1) The shipping container shall be capable of handling by conventional materials-handling equipment, such as forklift trucks, cranes, hand or power hoists, etc.

(2) The shipping container shall be stored so that the container will always be oriented in a horizontal attitude and a minimum of space utilized in quantity storage.

(3) The material of construction for the container shall be of fiberglass-reinforced polyester plastic.

(4) The container shall be designed for top loading with a parting line in a horizontal plane through the longitudinal centerline.

(5) The parting line shall be sealed with a gasket or gaskets, manufactured from neoprene or a material of equal chemical resistance.

(6) The shipping container shall be capable of stacking and shall be designed to support a loading equivalent to a minimum of three fully loaded, identical containers.

(7) The hardware required for securing the two halves of the shipping container need not be flush with the external surface, but should be protected from damage in handling and shipping. The hardware shall be designed so that the container can be opened or closed without the use of special tools. The container hardware shall be capable of a minimum of 10 opening and closing cycles without appreciable wear or malfunction. The design shall be such that replacement or maintenance and/or operation of the unit will be held to a minimum. The design shall incorporate features facilitating applicable maintenance, service, and operation at extremely low temperatures by personnel wearing heavy gloves or mittens.

(8) The plastic adapter shall be mounted within the container in a suitable shock-resisting or cushioned cradle, and capable of withstanding the performance tests specified below. Designs shall be furnished for a rubber shock-mounting system, a spring-mounting system, and a rubberized hair-felt, fiberglass cushioning, or similar materials.

(9) Performance test of shipping container shall be as follows:

(a) Vibration Test. Each container with a loaded adapter in place shall be capable of passing a 2-hr. vibration test similar to the ASTM-48T test. The test imposes a force of approximately 1 g on the specimen. Stack one loaded shipping container on another, and repeat the vibration test as above.

(b) Drop Test. One end of the loaded shipping container, when in its normal position on a concrete slab, shall be elevated to a clear height of 4 ft. and dropped. This procedure shall be repeated for the opposite end. Each end of the loaded shipping container shall be tested as per above for a minimum of six drops. No retarding gear shall be used in the drops.

(c) Compression Test. Each loaded shipping container shall be compression-tested with a minimum weight equivalent to three times the weight of the shipping container with the adapter in place. Remove the loading, and repeat six times.

(d) Static-Pressure Test. Static-pressure-test each container with an internal air pressure of 5 p.s.i. The container shall hold this pressure without loss for a minimum period of 24 hr.

(e) -65°F. and 160°F. Temperature Test. A loaded shipping container, pressurized at 5 p.s.i. shall be placed in each of the surveillance chambers listed above for a period of 9 wk. The containers shall be visually examined for any material or structural failures. A pressure reading shall be taken at periodic intervals.

(10) A check valve shall be provided such that a sample of the internal atmosphere in the shipping container may be drawn through a glass tube which is 1-5/8 in. long by 5/32 in. in diameter.

(11) A compartment for desiccant, complying with Specification MIL-D-3464, shall be provided with a ready-access airtight door or opening for replacement of desiccant. The quantity of desiccant required shall be calculated by the formula given in Specification MIL-P-116. An electronic sensing device or humidity indicator shall be included in the design of the container, located at as great a distance as possible from the desiccant. The humidity-sensing element should be capable of replacement without opening the container.

Design of the shock-isolation system was created by Container Laboratories, Inc., under subcontract to Universal Moulded Products. This system, as can be seen in fig. 15, consists of a steel cradle to contain the cluster and a series of shock mounts to damp out the loads applied to the container itself. Four shock mounts located on the sides in pairs take out the longitudinal loads; four located in pairs on each end take out the lateral loads; and eight mounts, four at each end, are designed to relieve the vertical loads. In addition, the cradle is mounted on four skids which protrude through the container shell. Each skid is equipped with a pair of shock mounts through which all vertical loads are damped.

The container shell itself is independent of the shock-isolation system and serves chiefly as the airtight housing for the cluster. It is only strong enough to withstand stacking loads, impact loads, and fatigue loads induced by vibration.

The cluster is lowered into the cradle by means of the cluster-handling clamp and sling, as shown in fig. 16. The cluster secured in place in the cradle can be seen in figs. 17 and 18.

b. Handling Equipment.

In the course of developing the various components of the chemical warhead system, the need for special handling equipment became evident. Every effort was made to utilize standard tools and equipment to the maximum extent. However, some functions did not lend themselves to the use of any standard Ordnance equipment. Three pieces of equipment were designed, developed, and proved in field operations: (1) warhead handling sling, (2) warhead loading stand, and (3) cluster handling clamp.

The first of these, the warhead handling sling, was designed by the Glenn L. Martin Co. simultaneously with the design of the nose casing. It is used in handling both unfilled and, eventually, the loaded fin-stabilized warhead casing, as well as both the unfilled and loaded nose casings. Use of this sling is illustrated in appendix A.

The warhead loading stand used in assembling the nose is a tubular steel structure mounted on four legs. The E125 cluster is lowered onto the stand in a vertical position, with the aft end down. The nose casing is then lowered over the cluster and secured to the X-frame by four bolts at the base of the cluster.

A cluster handling clamp was developed which simplified the handling of the E125 cluster during the various storage, shipping, and assembly operations. This clamp is a two-piece arrangement, hinged at one end of the two segments and having a latch to bring the other two ends together. The clamp is fitted with two trunnions opposed to each other, to which a hoisting sling can be attached. The cluster adapter is fitted

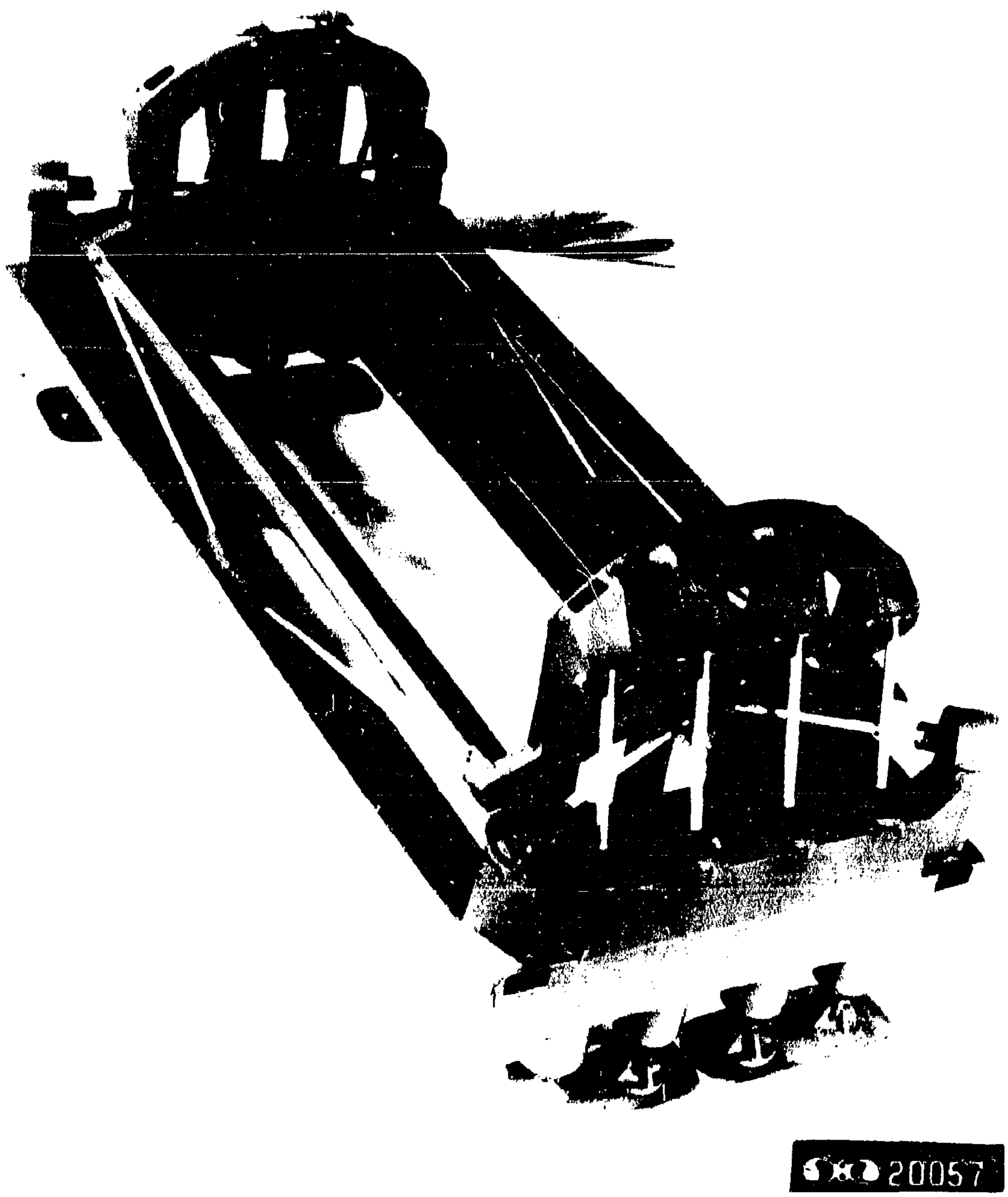

FIGURE 15

SHOCK-ISOLATION MECHANISM FOR REUSABLE SHIPPING CONTAINER

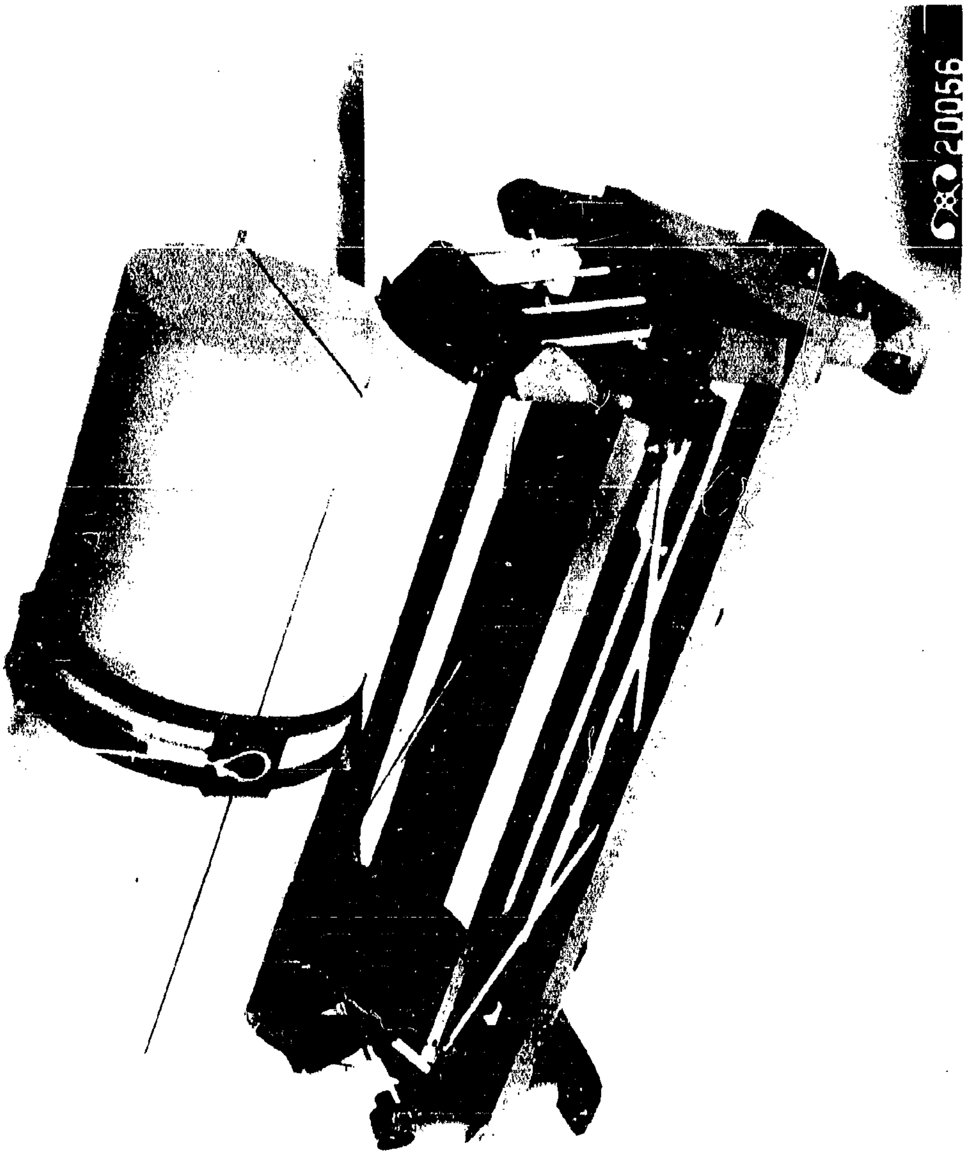

FIGURE 16

E125 3,000-LB. CLUSTER BEING LOWERED IN PLACE IN SHOCK-ISOLATION MECHANISM

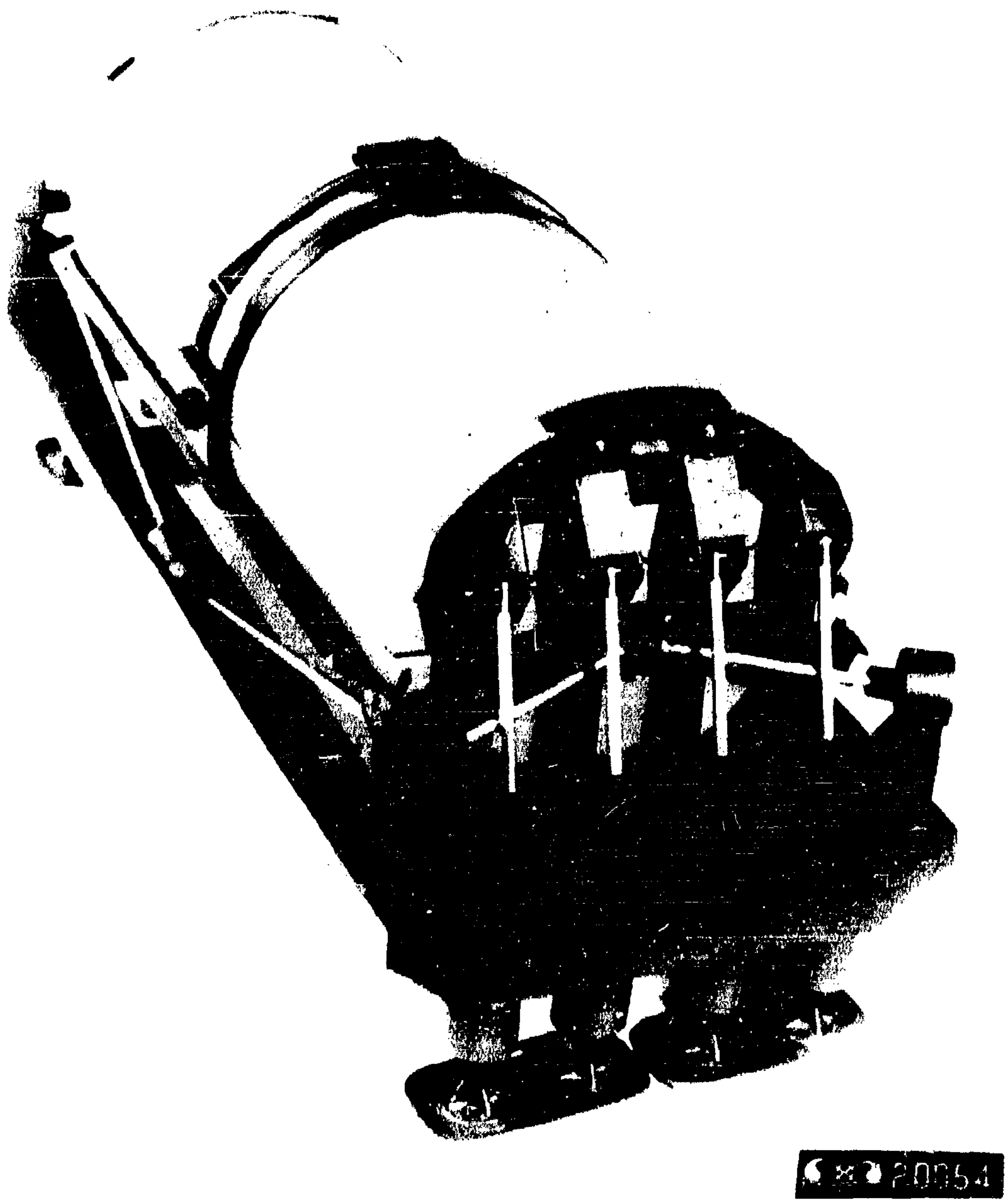

FIGURE 17

END VIEW OF E125 3,000-LB. CLUSTER IN PLACE AND LOCKED IN SHOCK-ISOLATION MECHANISM

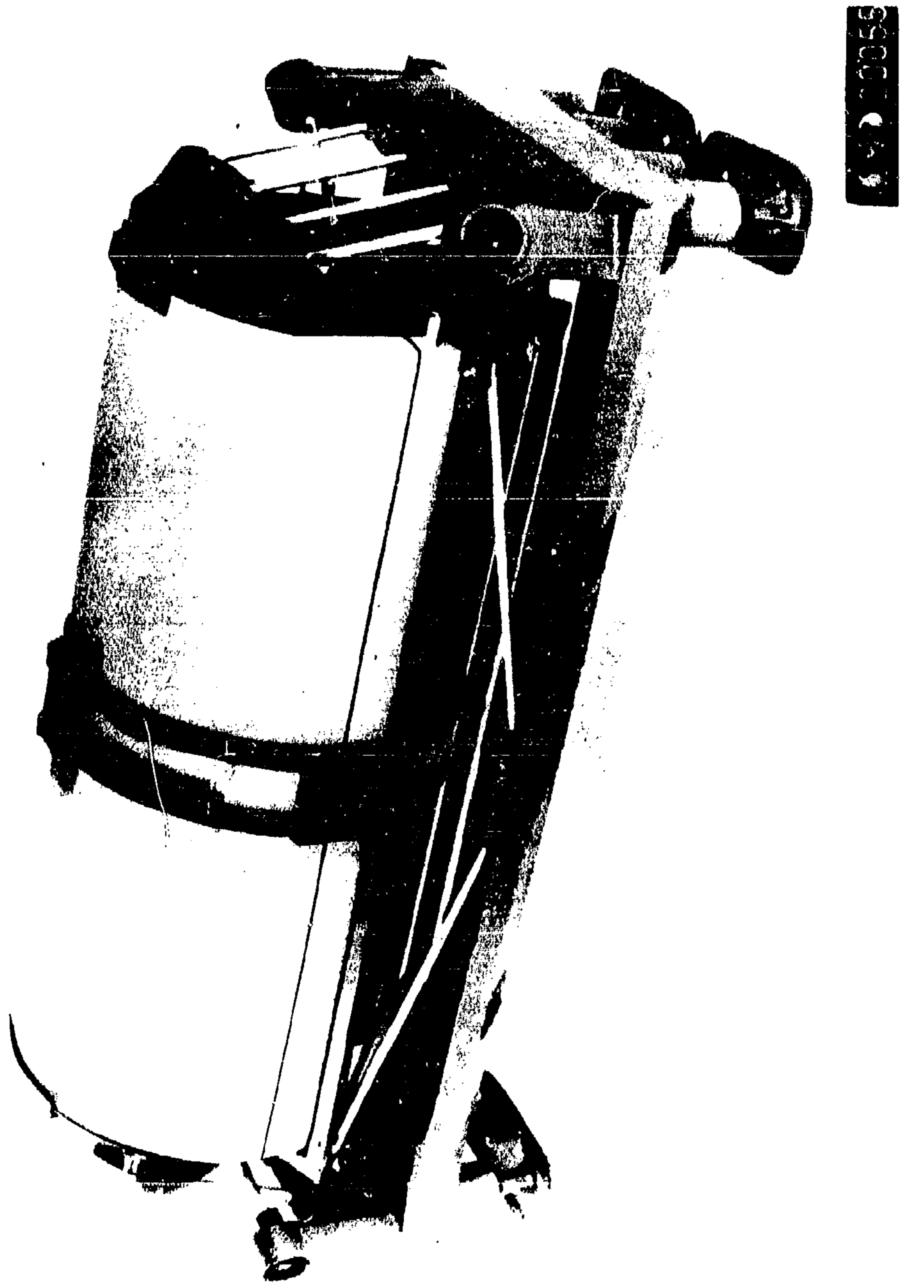

FIGURE 18

SIDE VIEW OF E125 3,000-LB. CLUSTER IN PLACE AND LOCKED IN SHOCK-ISOLATION MECHANISM with two studs located approximately 6 in. forward of the cluster center-of-gravity and diametrically opposed. These two studs serve as stops and also locate the clamp in such a way that the center-of-gravity of the cluster is slightly aft of the center of the trunnions. This allows the cluster to be raised and rotated easily with only a small degree of unbalance, but with the cluster base always tending to swing downward as desired. At the time the project was terminated, a tentative change had been planned which would provide a more positive method of handling by supporting the cluster base in addition to the trunnion supports. This redesign was never accomplished.

It was decided that the handling clamp should be furnished with each shipping container, since the clamp is required at both the assembly plant and the warhead loading site. The clamp would be used at the assembly plant tp transfer the cluster to the shipping container and would remain in place during transit. At the loading site it would only be necessary to attach the hoisting sling to the clamp. When the loading operation is completed, the clamp would be stowed in the shipping container for transshipment back to the assembly plant.

3. Test Equipment.

a. Fin-Stabilized Warhead.

In order that a comprehensive program of dynamic testing could be executed, some method of simulating the missile terminal dive was required. Since the fin-stabilized warhead test vehicle was used successfully on the earlier YSSM-A-1 program, it was decided that a similar test vehicle should be used in the SSM-A-1 program. The Glenn L. Martin Company made a study based on a rocket-boosted vehicle which would exactly reproduce the B-61A terminal-dive ballistic path in terms of velocity and attitude. A concurrent study was conducted on a free-fall vehicle and compared with the boosted version. Calculations for the rocket-boosted vehicle were based on the use of the aerojet T-27 solid-propellant rocket delivering 6,000 lb. of thrust for 7 sec. Its total weight is 498 lb.; its diameter, 12.9 in.; and its length, 64.25 in. The flight program called for a free fall from release to 20,000 ft., at which time the booster was fired. Results of the study indicated that SSM-A-1 dives could be duplicated in the altitude range of 44,000 ft. down to 32,000 ft. under proper combinations of release altitude, release velocities, and booster firing altitudes. However, the concurrent study on the free-fall test vehicle showed that dive angles and velocities could be achieved by the time the test vehicle had reached the range of warhead opening altitudes, i.e., from 15,000 ft. down.

On the basis of the preceding study it was decided that the complexity of the rocket-boosted test vehicle was much too great in terms of the slight gain in performance. A contract (DA-18-108-CML-3462) was awarded to the Glenn L. Martin Co. for the fabrication of six fin-stabilized warhead free-fall test vehicles, whose performance was guaranteed to duplicate within 3% the performance of the SSM-A-1. All design and development work required for this project was authorized under an existing Air Force research and development contract. This was done to expedite delivery of the final items and to take advantage of the time required for negotiation of the Chemical Corps contract.

The nose section of the test vehicle is identical with the production design and is attached to the boattail afterbody by the four explosive bolts. The assembled vehicle (fig. 19) is 347 in. long, having a maximum body diameter of 54 in. and a fin diameter of 64.125 in. The design is of conventional aircraft construction using aluminum alloy throughout with the exception of the explosive-bolt splice fittings and the drag pin hole. Design and manufacture of the test vehicle preceded the design and development of the T1404 fuze which resulted in the forced omission of any provisions for fuze mounting and electrical installation. Wiring was provided from the power receptacle on the center section bulkhead to the four explosive-bolt receptacles. Interim provisions for all other electrical installations were the responsibility of these Laboratories.

The configuration of the test vehicle was coordinated with Consolidated-Vultee Aircraft Corp. to insure proper installation and fit in the bomb bays of the B-36F aircraft. The limiting dimensions of the test vehicle by coincidence were very nearly identical with those of the 43,000-lb. GP bomb, for which racks were designed and available, making the installation in the bomb bay a relatively simple matter.

Upon delivery to these Laboratories a modification program was effected in which two battery racks were added to the aft side of each center section bulkhead. Necessary electrical installations were made, and mounting provisions were made for the interim fuze system.

The power source selected for the system was a pair of 27-v. d-c. dry cells manufactured by the Bright Star Battery Co. All components, with the exception of the explosive bolts, were mounted in a dual arrangement with a series-parallel circuit to increase the probability of functioning.

b. Floating Bomb Marker.

Dynamic testing in the final engineering phase is conducted primarily on the fin-stabilized warheads. However, these Laboratories felt that recommendations for standardization could not be made without one or more successful flights on the B-61A missile. Although missiles were available to support this program, the problem was one of getting data from the test on a water target. To overcome this obstacle a program was initiated to develop a modified E54R6 bomb which would leave a visual reference point on the surface of the water.

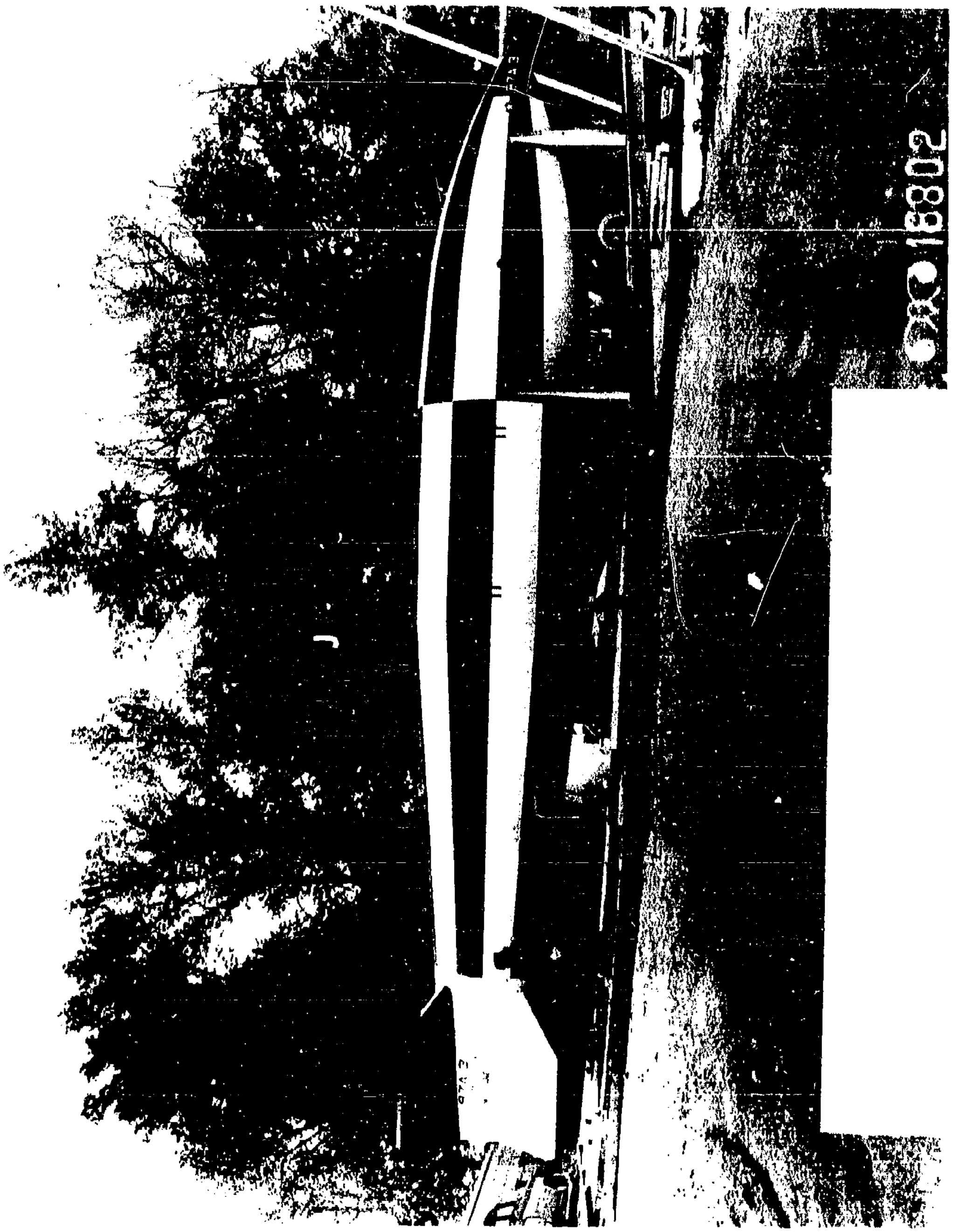

FIGURE 19

PROFILE VIEW OF B-61A FIN-STABILIZED WARHEAD

Two methods of marking the surface of the water were considered: (1) by fluorescein dye marker and (2) by an inflatable marker. Past experience with dye markers proved their feasibility but the dye was not easily reproducible by photography. Also, it was doubtful whether the dye mark would be able to resist the effects of wind and waves on an ocean target. The third drawback was the overlapping of marks when the bombs impacted close together. On the strength of this past knowledge it was decided that the inflatable marker should be investigated first.

Preliminary work was directed at photographing various size markers through an altitude range of 5,000 to 20,000 ft. A plastic marker 6 ft. in diameter set adrift in the Gunpowder River was photographed from a B-17 equipped with a Fairchild K-17 camera. The B-17 made four passes over the marker at 5,000, 10,000, 15,000, and 20,000 ft. The marker was not visible on the film at 15,000 and 20,000 ft., just barely visible at 10,000 ft., and fairly obvious at 5,000 ft. The enlarged image was clearly defined at 5,000 ft.

Development of the modified munition proceeded from this point, beginning with packaging of the marker. The space available for the marker was approximately the space available for agent plus the space taken up by the burster. The marker which was finally selected was 4-ft. square of latex-coated nylon with an inflatable edge 2 in. in diameter. Inflating valves which were identical with those used on inflatable life vests were attached on each of two opposed corners. This can be seen in fig. 20, which shows the marker inflated. The marker was packed in such a manner that the valve stems and CO_2 cartridge holders were located at the rear of the munition. This complete assembly was packed around a spool which fitted snugly inside the munition casing.

The E24R1 fuze was modified by drilling and tapping its base to receive the marker rod which passes longitudinally through the marker spool. The detonator was retained in the fuze to provide the energy necessary to eject the marker.

The bomb casing was cut into two halves, and an inner liner was spot-welded on to act as the retainer for the casing halves when the munition was assembled.

The modified munition functions as follows: (1) Upon release of the munition from the cluster, the delay functions and releases the parachute as in a normal E54R6 munition; (2) upon impact the striker pin fires the detonator, which, in turn, shears the threads in the tapped hole and releases the marker package; (3) simultaneously, the sudden acceleration of the package punctures the CO_2 cartridges and starts inflating the marker; (4) all extraneous parts fall away and sink, leaving the marker fully inflated on the surface. Fig. 21 shows the internal stowage of the components.

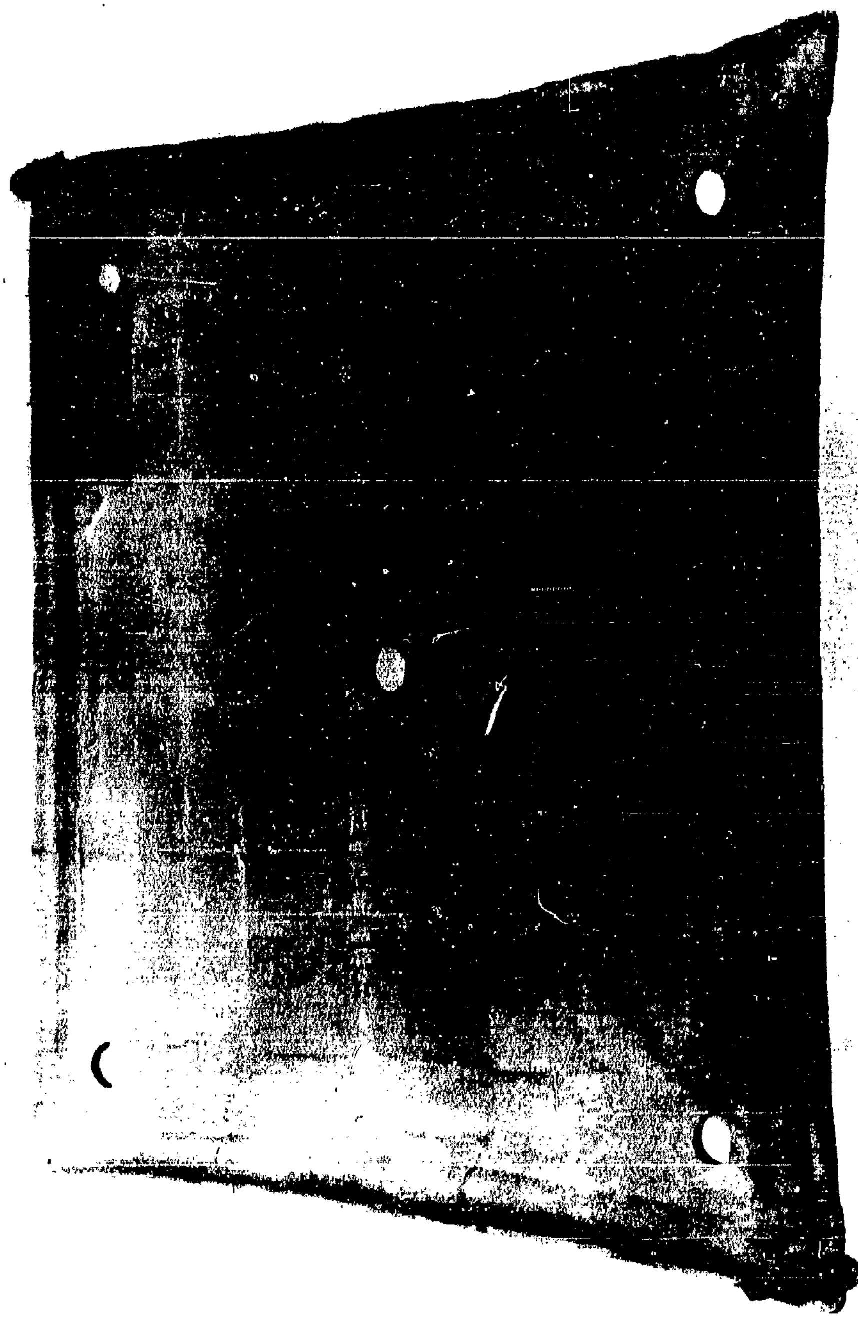

FIGURE 20

E54 FLOATING BOMB MARKER

FIGURE 21

EXPLODED VIEW OF E54 FLOATING MARKER BOMB

Limited tests conducted on the modified munition indicated a practical solution, requiring only minor revisions to complete the development. The cancellation directive prevented any further effort on this subtask, and the program was halted before its worth could be fully established.

4. Arming and Monitoring.

The capability of the MATADOR to carry a series of warheads which, in general, have nothing in common, posed the problem of providing a single warhead arming and monitoring system which would satisfy the requirements of all warheads.

At a meeting of the MATADOR Warhead Coordinating Group on 6-7 February 1952 at the Air Force Missile Test Center, this problem was discussed jointly for the first time (6). As a result, two basic premises were established to guide the development of the system: (1) The warhead should be armed whenever the missile is over enemy territory and unarmed when over friendly territory; and (2) once armed, the missile cannot return to friendly territory. Also, the terms "bomb arming signal" and "electrical arming signal" were accepted and defined as follows:

> "a. Bomb arming signal: The signal which removes the 'safe' features of the warhead so that it will detonate on receipt of a 'fire' signal (electrical or otherwise).
>
> "b. Electrical arming signal: The signal which makes a fuze ready for action. In the child-type warhead, the signal will activate the separation timing function."

The time at which the warhead should be electrically armed was determined to be at the initiation of the terminal dive of the missile and then only after a bomb arming signal has been received.

Complicating the problem is the utilization of either the MSQ-1 guidance system (microwave command control) or the Shanicle guidance system (microwave hyperbolic navigation system) or a combination of the two to bring the missile over the target. A third flight condition exists where the missile is guided to the Shanicle hyperbolic grid by means of a dead-reckoning system independent of the MSQ-1. The application of these systems results in a total of four flight conditions and a variation of the arming method for each.

Summarized, they are (7, 8):

Guidance system	Arming method
(a) MSQ-1 to target	(a) Warhead armed on receipt of MSQ-1 bomb arming signal.
(b) MSQ-1 to Shanicle. Changeover in enemy territory	(b) Warhead armed on receipt of MSQ-1 bomb arming signal.
(c) MSQ-1 to Shanicle. Changeover in friendly territory	(c) MSQ-1 arming signal given prior to changeover starts an arming timer. Upon expiration of a preset delay, after which missile is assumed to be over enemy territory, warhead is armed automatically.
(d) Dead reckoning to Shanicle	(d) Warhead is automatically armed after a preset time delay, following the attainment of a predetermined missile velocity.

Returning to the two basic premises established at the warhead meeting, it can be seen that the facts presented by the first are obvious. During the initial phase of the flight the missile may cover as much as 440 mi. within friendly territory (guidance limits the range of the missile within enemy territory to approximately 250 mi.). Over this range the missile must be unarmed in the event of a malfunction, which would cause the flight to be terminated prematurely. After crossing into enemy territory, it is equally desirable to have the missile armed as soon thereafter as is possible so that the warhead would inflict as much damage as possible in the event the missile was unable to reach the target. Depending on the method of guidance employed for a given flight, the accuracy with which the point of crossover into enemy territory can be ascertained ranges from 500 ft. for "MSQ-1 to target" to 37 mi. for "dead reckoning to Shanicle."

The flight path of an armed missile must be limited to insure that the missile cannot return to friendly territory due to loss of control, enemy countermeasures, or for any other reason. This insurance is accomplished by the directional gyro coupled with the heading-error switch and by the turn-rate limiter, whose function is to provide an automatic dump signal in the event the heading limits or turn-rate limits are exceeded. A schematic diagram of the arming and monitoring systems is also shown in fig. 22.

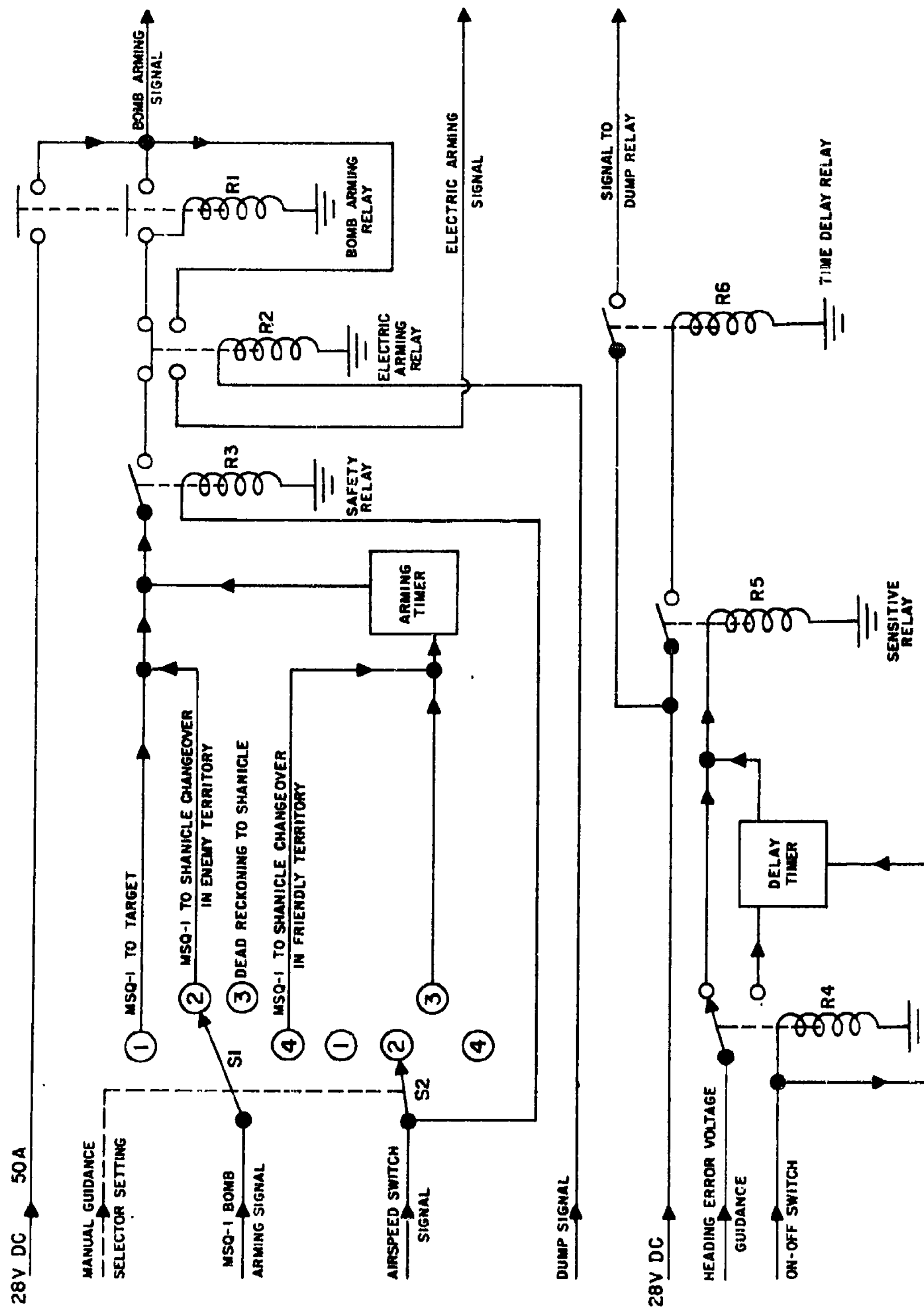

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FIGURE 22 (7)

SCHEMATIC OF ARMING AND MONITORING SYSTEMS OF MATADOR

B. Flight Tests.

The ultimate objective of all of the work accomplished up to this point was the dynamic testing of the warhead. As mentioned previously the fin-stabilized warhead casing was designed and produced as a vehicle suitable for testing the complete warhead configuration.

1. Establishment of the Test Program.

As originally conceived, the dynamic test program was divided into two phases, (1) development testing and (2) final engineering testing. Phase I was to be accomplished by use of the fin-stabilized warhead test vehicle; phase II called for eight flights on B-61A missiles. It became apparent that phase II would probably run into several conflicts in the way of schedules, test facilities, etc., with the missile program, because of the higher-priority special warhead program and also because of the objectives of the missile test program as a whole. This problem was discussed at meetings of the MATADOR Warhead Advisory Group and resulted in a joint decision to continue with the use of the fin-stabilized warhead casings in phase II. However, it was also made clear by the representative of the Chemical Corps that such a program could not lead to standardization of the warhead and its components without a minimum number of flights on the B-61A missile. It was then agreed that three missile flights would be scheduled as acceptance tests unless the requirements for the missile flight tests were waived, in which case the Air Force would authorize standardization on the basis of the fin-stabilized warhead tests alone.

As a result of the above decisions Air Materiel Command contracted with the Glenn L. Martin Company to manufacture and deliver to the Chemical Corps 24 additional fin-stabilized warhead casings, 8 of which were to be used for phase II on this project and the remainder to be used on the other chemical warhead projects for the MATADOR.

A test procedure was prepared (see appendix A) establishing test conditions and the handling and loading procedure. A resume of the data to be obtained is as follows:

1. Aircraft altitude

2. Aircraft velocity

3. Aircraft azimuth

4. Release altitude

5. Warhead-separation altitude

6. Cluster-opening altitude

7. Time from release to warhead separation

8. Time from warhead separation to cluster opening

9. Aircraft position data at time of release with reference to "Tarzon" target or N.A.A. tower

10. Missile position data at time of warhead separation with reference to "Tarzon" target or N.A.A. tower

11. Warhead position data at time of cluster opening with reference to "Tarzon" target or N.A.A. tower

12. Wind and temperature data aloft to release altitude

13. Bomb pattern

From these collected data it was expected that a realistic evaluation of the warhead system could be made. Under phase I it was expected that all mechanical and electromechanical and handling difficulties could be resolved within the space of the six vehicles assigned. Phase II would have as its prime purpose the evaluation of warhead effectiveness, effect of opening altitude on pattern, effect of winds aloft on aimability, and effect of delayed opening of warhead on pattern.

Arrangements were completed through Wright Air Development Center for the use of facilities and aircraft at Walker Air Force Base, New Mexico, and Holloman Air Development Center, New Mexico; and also support as required from Air Force Armament Center, Florida, and Wright Air Development Center.

Air Force planning and scheduling required an interim stockpile of an undetermined number of E6 warheads, and Air Research and Development Command agreed to classify the first six flight tests as Air Force phase VI testing as defined by AFR 80-14 dated 11 September 1951. These were the warheads used in phase I, described below. The production stockpile was to be determined at the completion of the evaluation of the over-all program. The phase VI classification also established the Air Force Armament Center as the agency having prime responsibility for the conduct of the tests. The Chemical Corps was responsible for supplying all equipment and personnel required. The program was a joint effort in which all agencies contributed where best fitted and, for the sake of expediency, performed functions which were not necessarily responsibilities of that particular agency.

2. <u>Execution of Phase I</u>.

a. <u>Tests of FSW 87A-2 and FSW 87A-5</u>.

Two E125 clusters were assembled with 306 E54R6 bombs each having simulant fill, sand-filled bursters, and E24R1 fuzes with live primers.

Some difficulty was encountered in latching the adapter halves, due to the size of the cork liners used and to the roughness of the interior surface of these adapters, which were among the first units delivered.

At the same time, two fin-stabilized warhead casings were modified to incorporate battery racks, delay detonator holders, timer brackets, and the necessary electrical work to provide the proper circuitry. On these two units the timers were mounted on the center-section access door for accessibility.

Plans were made to test these two fin-stabilized warheads, 87A-2 and 87A-5, on 3 June 1953, and the materiel was shipped to Walker Air Force Base for assembly.

During the assembly of FSW 87A-5 two of the explosive bolts inadvertently detonated, rupturing the bolts and rendering the casing temporarily useless. Analysis of the incident indicated that the detonation probably resulted from deviation from the prescribed procedure. At the time of bolt detonation the batteries had been plugged in, so that insulation could be applied over the entire battery. This was a field modification and was not included in the assembly procedure, with the result that the operational sequence was disrupted. The timer microswitch was not connected at the time of the incident, and the bare leads were left dangling inside the center section. Detonation occurred shortly after two blasting caps had been prematurely installed and plugged in. While the exact cause of the detonation is not definitely known, it is believed that the bare microswitch leads became grounded to the missile structure, thus completing the circuit.

FSW 87A-2, which had previously been completely assembled without incident, was undergoing final checks prior to loading in the aircraft. The center section door was being removed in order to set the timers and install the arming wires, when all four bolts detonated. Again, the exact cause of premature detonation could not be established, but indications are that contact was somehow made across the exposed microswitch terminals, either by static or by grounding across the framing at the bottom of the door opening. The technician who removed the door was shocked and temporarily deafened by the explosion and could not clearly remember precisely what had been done at the instant of detonation. No further attempt was made to conduct the tests until the entire system could be reviewed and modified. The two fin-stabilized warhead casings were not damaged and required only minor rework to the nose casing bolt fitting.

The complete electrical system was studied by the Glenn L. Martin Co. and redesigned (see fig. 23) to incorporate certain safety features to insure that radiofrequency and static charges would not cause detonation. A 15-ohm, 10-w. resistor was incorporated on the positive side of each electric blasting cap and delay detonator, and a master

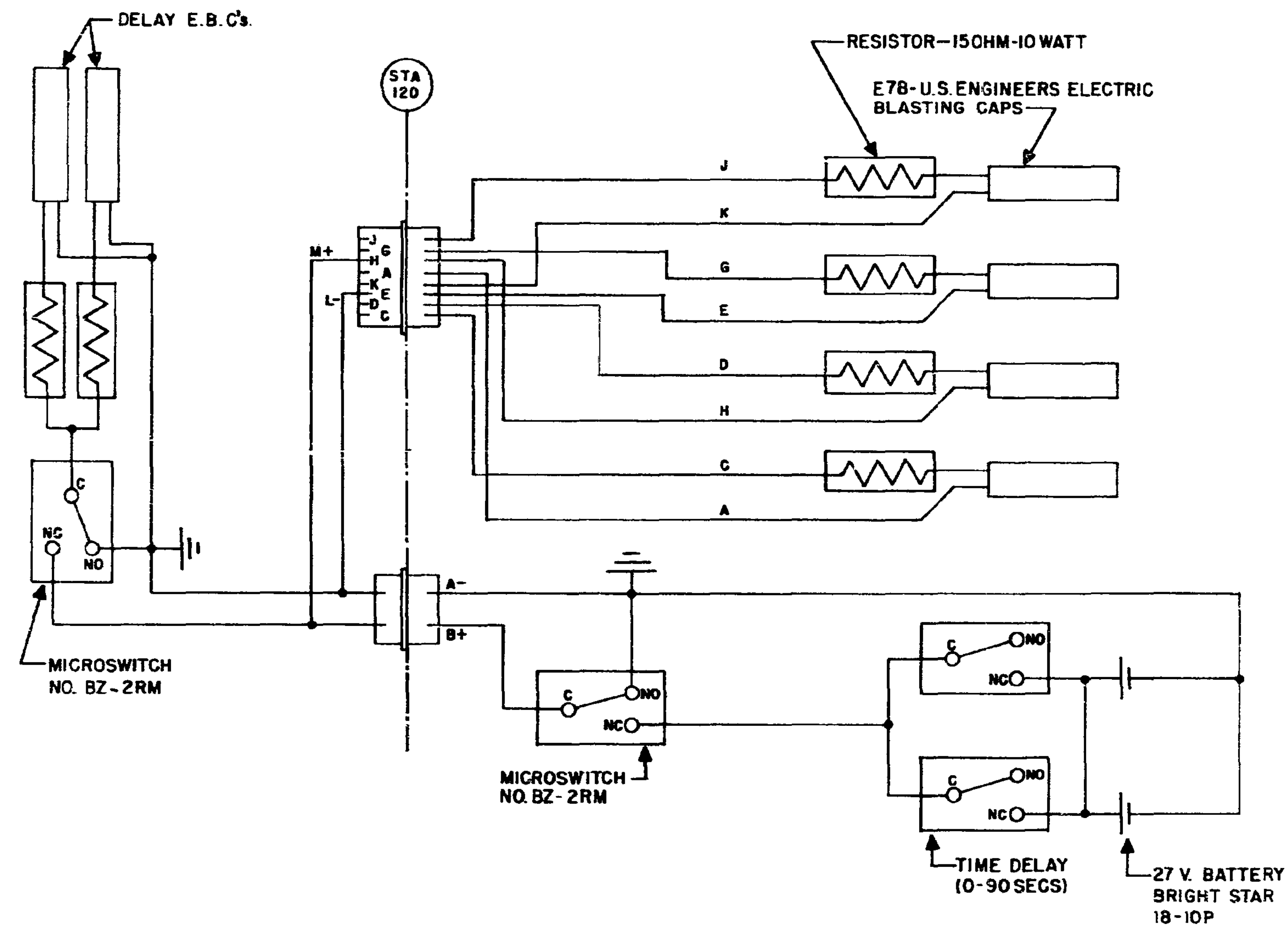

FIGURE 23

WIRING DIAGRAM FOR B-61A FIN-STABILIZED WARHEAD switch, grounded in the open position, was put in the circuit. In addition, the timer microswitch was inclosed in an insulated housing, and the complete assembly was mounted on the frame adjacent to the access door instead of on the door itself (fig. 24). All wiring was sheathed in plastic conduit and shielded against moisture (fig. 25). As a final precaution, the interiors of the missiles were vacuumed to remove manufacturing debris (metal chips and shavings).

Attention was next turned to the cold-temperature behavior of the battery. One Bright Star battery selected at random was stored at -40°F. for 24 hr. Readings were taken every 15 min. for 8 hr. and a final reading at the end of 24 hr., whereupon the battery was removed from cold storage, and readings were taken every 15 min. Just prior to storage the battery voltage was 25.6 at 75°F. No change was recorded until the end of the fifth hour, when the reading showed 25.3 v. At 8 hr. the reading was 24.4 v.; at 24 hr., down to 1.0 v. After removal from cold storage the voltage was restored to the original reading of 25.6 v. in 1.5 hr. This test was not conclusive in that the battery was in a "no-load" state. The same type battery functioned consistently in high-altitude-low-temperature tests of the timer and the delay detonator in which the temperatures were lowered to -40° and -65°F. at a pressure of 23 in. Hg. These tests gave a better indication of the capacity of the battery.

The Glenn L. Martin Co. meanwhile set up breadboard models of the system and determined the rate of discharge of the batteries when the circuit was closed. Results of this survey indicated complete discharge of the batteries in less than 1 sec. Because of doubts as to the ability of the battery to deliver at its rated capacity, it was decided to investigate other types which could sustain a load over longer intervals. It was found that no other dry cells matched the Bright Star in performance; any suitable wet cell was extremely costly, requiring special handling and charging, which it was felt would be difficult if not impossible to provide in the field.

The final step in refining and improving the operation was the rewriting of the procedure manual, which ultimately resulted in the form given in appendix A. A copy of the rewritten manual was submitted to the field test engineers at the Glenn L. Martin Co. for comment and recommendations and was approved in its original form.

b. <u>Test of FSW 87A-3</u>.

Upon completion of the investigation and redesign of the electrical system, plans were made to continue with the test program. FSW 87A-3 and FSW 87A-6 modifications were completed and both test vehicles were shipped to Walker Air Force Base for tests on 7 October 1953 (9).

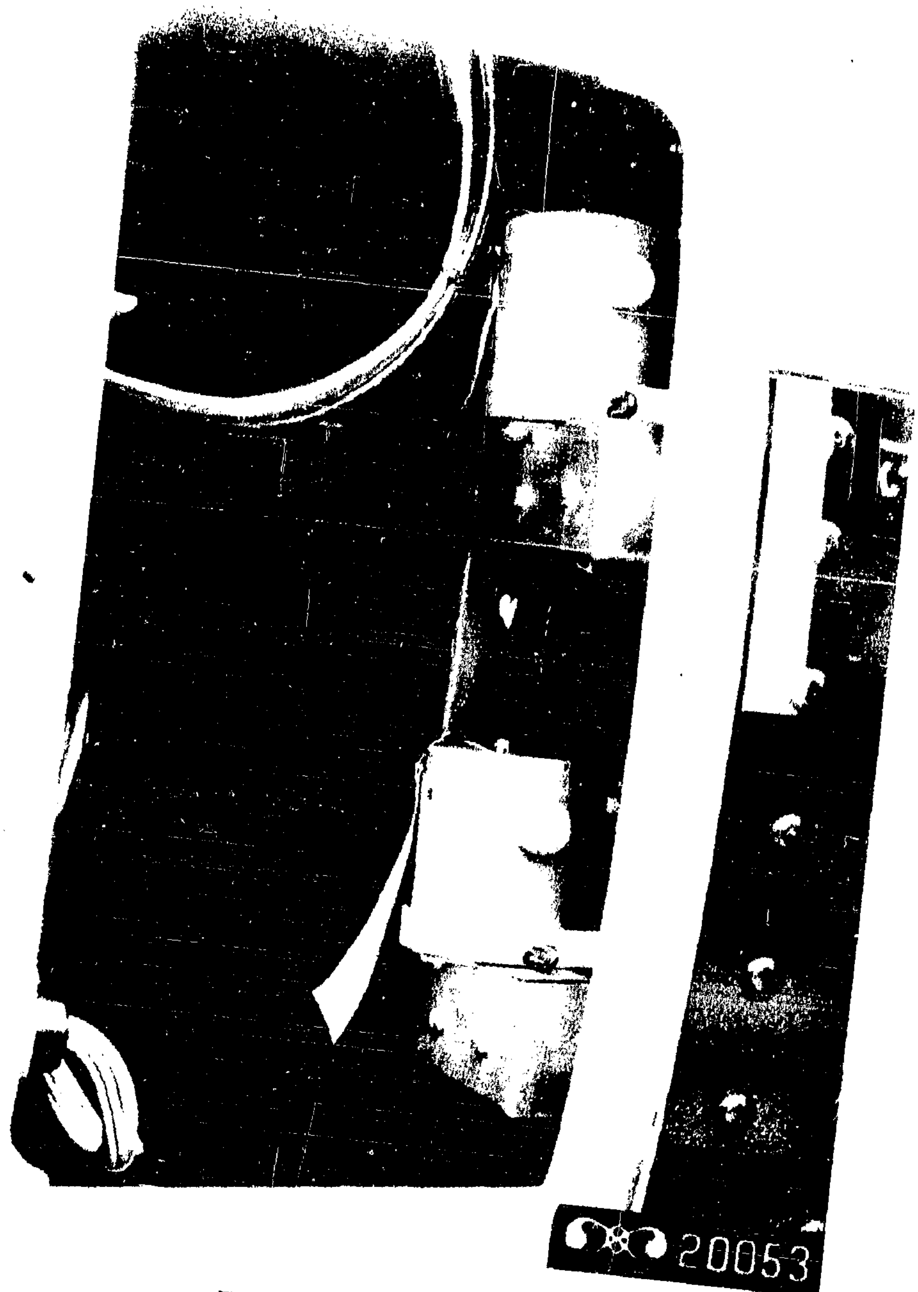

FIGURE 24

VIEW OF TIMER INSTALLATION MOUNTED INSIDE CENTER SECTION

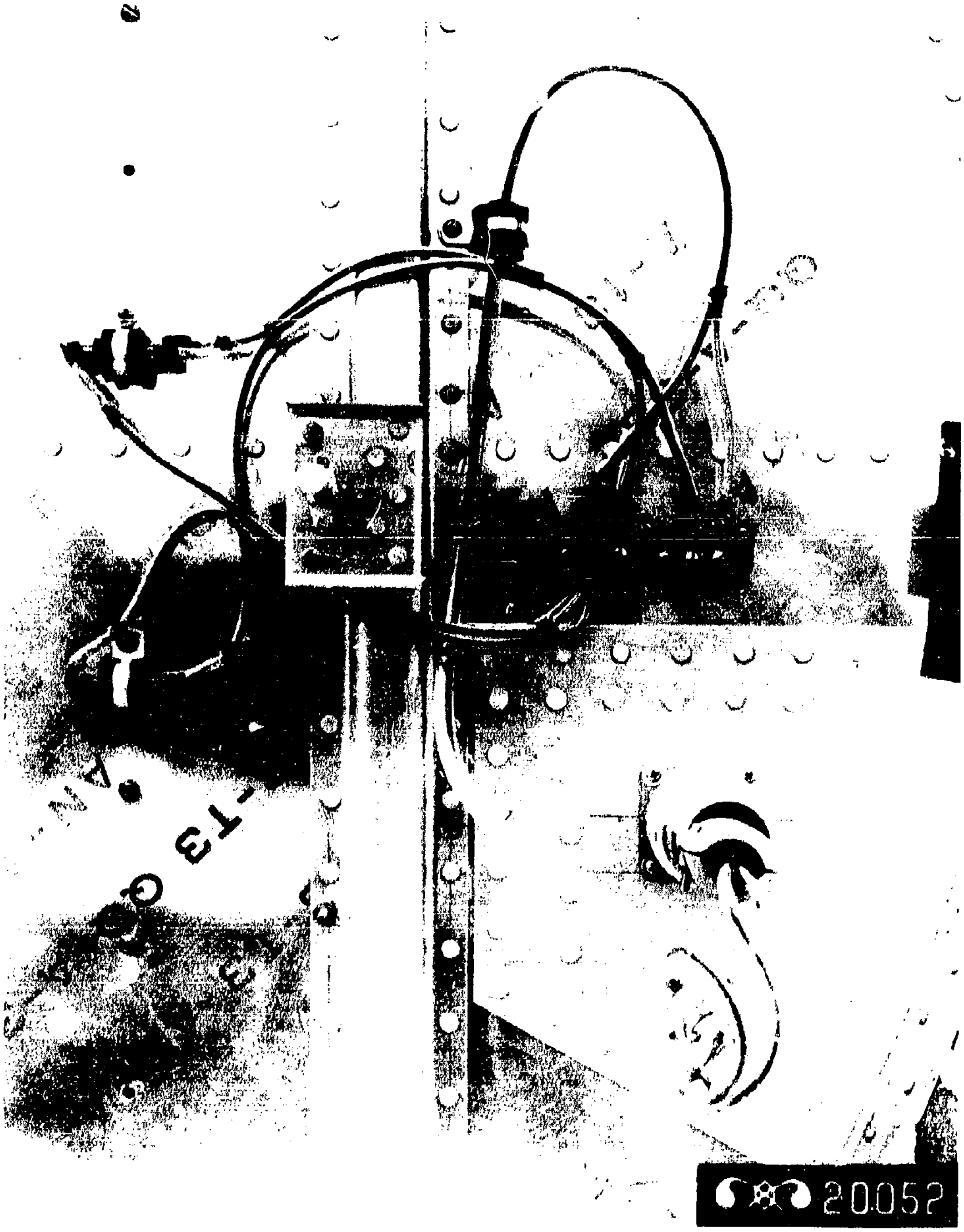

FIGURE 25

VIEW OF WIRING INSTALLATION ON CENTER SECTION BULKHEAD

Of the two clusters, which had remained in outside storage at Walker Air Force Base (see p. 62), one was found to contain enough water to almost certainly damage most of the bombs in the lower half and was consequently abandoned. The second cluster appeared to be dry and unharmed by the period of external storage and was installed in the nose of FSW 87A-3. The procedure manual was followed in detail in this operation, and all safety and operational checks were satisfactorily completed.

The conditions of test were as planned originally: release altitude, 35,000 ft. above mean sea level; release velocity, 350 m.p.h. true air speed; separation altitude, 10,000 ft. above target.

The mission was carried out as planned, but the warhead failed to separate from the afterbody, and the mission resulted in an intact impact. Subsequent excavation work at the impact site failed to yield any clue as to the cause of failure. Excavation and screening were seriously hampered by the terrain, which prevented the use of suitable earth-moving equipment. The movies taken from the Mitchell cameras showed definite smoke puffs at the separation altitude, which indicated that one or more explosive bolts had detonated. FSW 87A-6 was carried over to the next test, with FSW 87A-4.

c. <u>Test of FSW 87A-6 and FSW 87A-4</u>.

In the absence of any definite evidence of the cause of failure, there was no single component that could be pointed to with any certainty as the source of malfunction, and no changes could be effected for the next tests. The Glenn L. Martin Co. proposed that telemetering equipment be installed on the next FSW to furnish data on the functioning of the components. This was to be a field installation accomplished by Martin personnel. This proposal was approved by the Air Force; and in December 1953 two additional units, FSW 87A-6 and FSW 87A-4, were assembled at Walker Air Force Base (10, 11). Martin personnel made the telemetering installation in FSW 87A-6 with pickups at key points to measure voltages at the explosive bolts and delay detonators and to indicate whether or not the bolts sheared.

Representatives of Diamond Ordnance Fuze Laboratories were also on hand to conduct performance tests on the T1404 fuze. One T1404 fuze with recorders was mounted in each of FSW 87A-4 and FSW 87A-6. These installations were independent of the main fuzing system and were primarily intended to subject the fuze to conditions which could normally be expected in operational use. Fig. 26 shows the fuze compartment with the access door removed. The electrical receptacles can be seen on either side of the detonator holes. In fig. 27 the T1404 fuze is shown mounted in its bracket. The internal arrangement is shown in figs. 28 and 29, with the battery pack mounted on top of the fuze bracket on the left. The disk recorder is the cylindrical unit next to the battery pack.

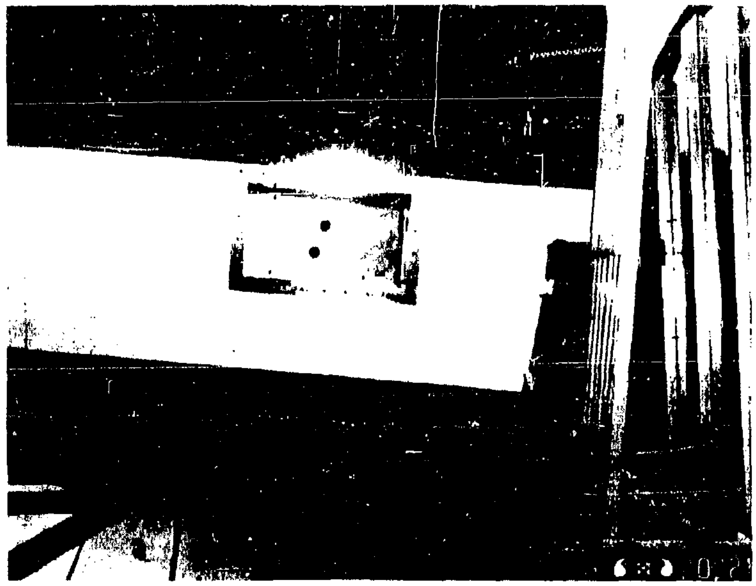

FIGURE 26

EXTERNAL VIEW OF T1404 FUZE MOUNTING BRACKET WITH ACCESS DOOR REMOVED

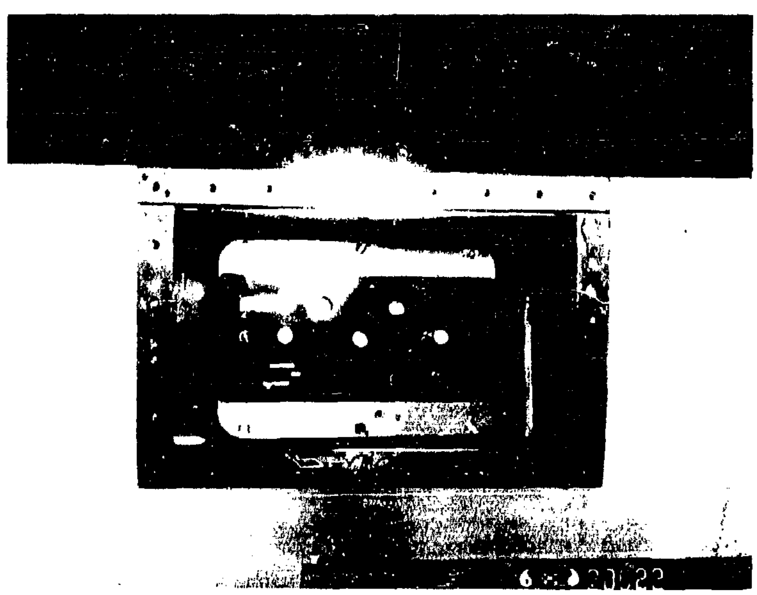

FIGURE 27

T1404 FUZE INSTALLATION IN NOSE SECTION

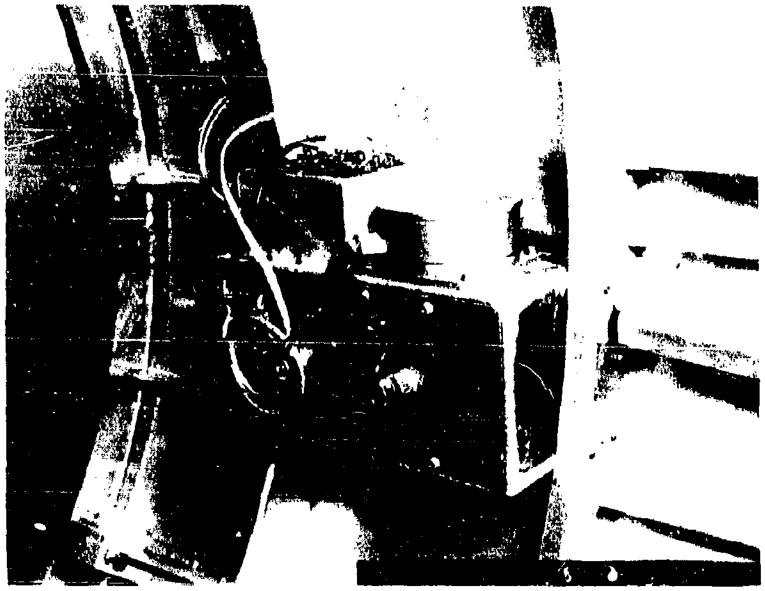

FIGURE 28

T1404 FUZE MOUNTING BRACKET WITH DISC RECORDER MOUNTED ON TOP

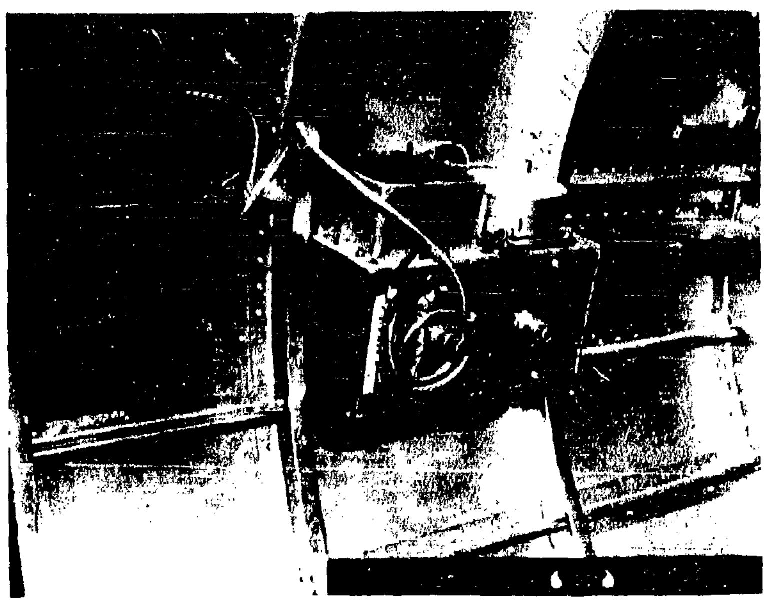

FIGURE 29

T1404 MOUNTING BRACKET SHOWING ACTUATING SWITCH INSTALLATION AT LEFT

During the preflight procedure for the B-36 aircraft, a fire of undetermined origin in the nose of FSW 87A-6 was reported by the crew chief. It was quickly determined that an electrical fire had started somewhere in the telemetering installation after aircraft power to the telemetering components had been turned on. All switches were turned off, and the mission was flown minus telemetering.

Both fin-stabilized warheads were released on 15 December 1953 under the same conditions as for FSW 87A-3. FSW 87A-4 was released first and appeared to function satisfactorily. FSW 87A-6 was released on the second run but failed to function, and an intact impact resulted. Recovery of the parts of the nose of FSW 87A-4 revealed that the nose breakup was not caused by the detonation of the primacord. The nose casing had separated mainly along the horizontal skin splices, with lateral breaks occurring on the upper half. Segments of primacord were still in place in the nose, although one of two delay detonators had fired. A study of the Askania film indicated normal separation at the proper time but that the warhead immediately had flipped up and over, with breakup complete in approximately 0.2 sec. From this it was obvious that the primacord did not break up the nose. What caused this premature breakup could not be determined, although several theories which had some merit were advanced. These Laboratories felt that the ram pressure exerted against the internal surfaces of the nose, after it had flipped over, exceeded the design limits of the nose casing and caused it to fail. On the other hand, the Martin people felt that the design was sound and that the stress analyses for these flight attitudes showed a margin of safety sufficient to prevent this type of breakup.

The type of failure noted in the remains of the nose casing tends to bear out the theory of ram pressure, as can be seen in fig. 30, where the 24ST splice frame tore away from the rivets in a direction along the longitudinal axis. In figs. 31 and 32 can be seen the failure in shear of the rivets along the longitudinal splices, which is the type of failure that could be expected from a breakup caused by ram pressure. Fig. 33 shows all of the recovered parts reassembled to give a graphic picture of the over-all breakup.

Proof of bolt separation was readily obtainable from the tail assembly (figs. 34 and 35), which showed clean, normal rupturing of all four bolts. Examination of the timers (fig. 36) showed that both had functioned normally and that the microswitches had been closed.

The T1404 fuze was recovered intact from FSW 87A-4. The disk recorder showed that one side of the fuze armed in 29 sec. and the other in 30 sec. The record also showed that each detonator circuit operated 4 sec. after arming. The discrepancy in the arming time was attributed to a slight misadjustment of the T3 clock movement. The T1404 fuze mounted in FSW 87A-6 was totally destroyed so that no record could be obtained.

FIGURE 30

FSW 87A-4 NOSE CONE SHOWING TYPE OF FAILURE INDICATING TEAR-OUT OF RIVETS

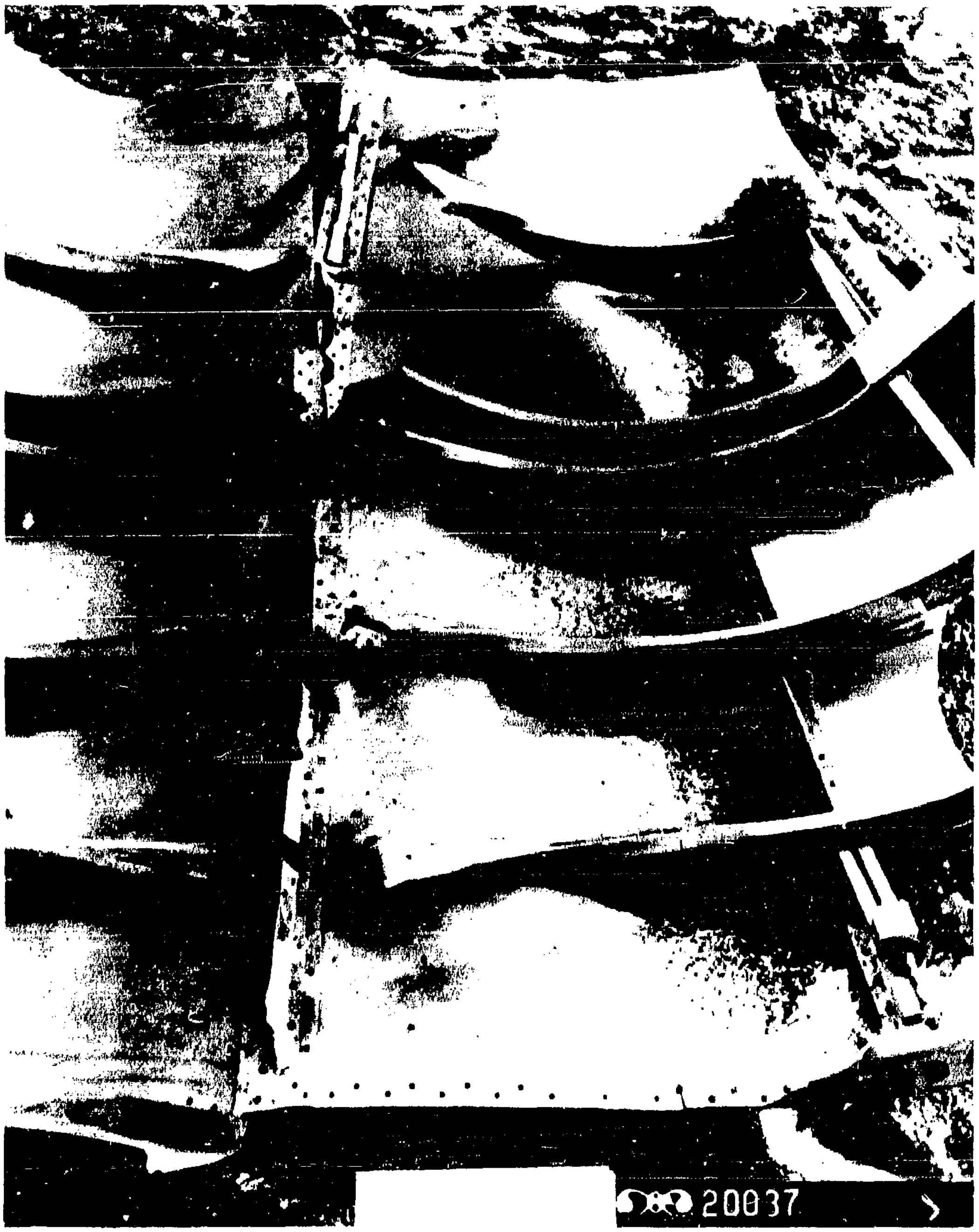

FIGURE 31

CLOSEUP OF LOWER HALF OF FSW 87A-4 NOSE SECTION
SHOWING UNSEVERED PRIMACORD SPLICE

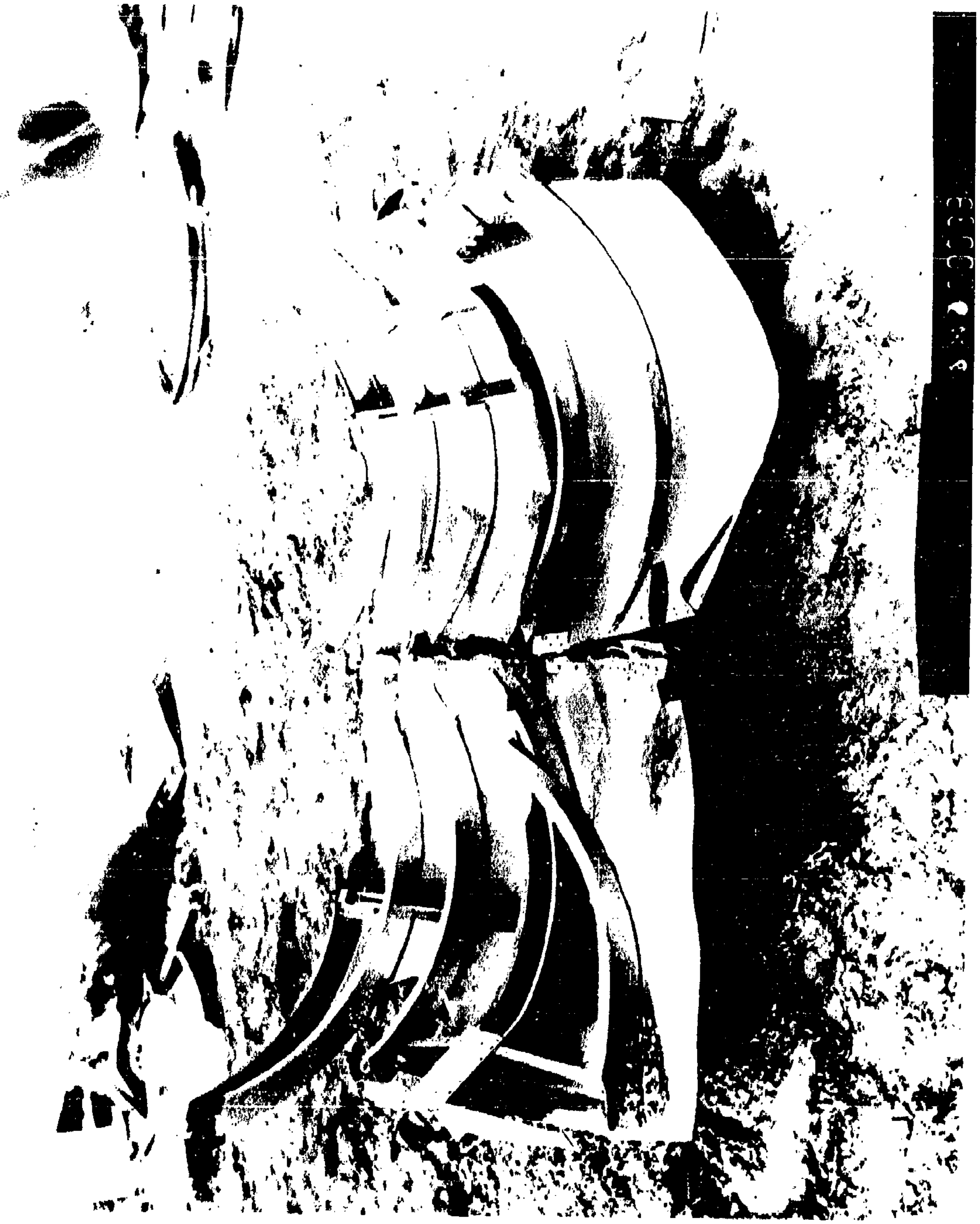

FIGURE 32

LOWER HALF OF FSW 87A-4 NOSE SECTION SHOWING UNSEVERED PRIMACORD SPLICE

FIGURE 33

REASSEMBLED PARTS OF FSW 87A-4 NOSE SECTION

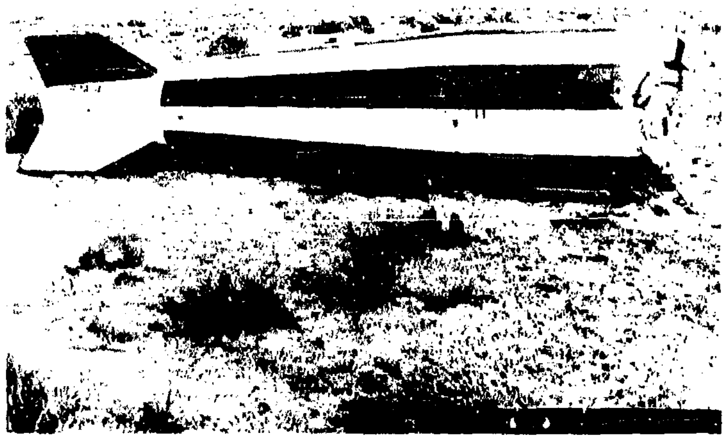

FIGURE 34

FSW 87A-4 TAIL ASSEMBLY AFTER IMPACT

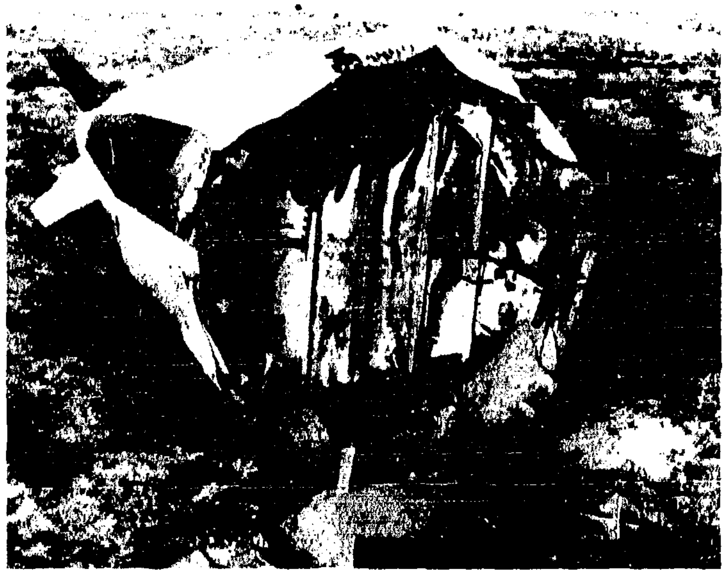

FIGURE 35

FSW 87A-4 CENTER SECTION BULKHEAD AFTER IMPACT

FIGURE 36

CLOSEUP OF FSW 87A-4 TIMER INSTALLATION AFTER IMPACT

Remains of FSW 87A-6 could not be immediately recovered, and further efforts were postponed temporarily. There was reason to believe that the failure was caused by at least one defective jack plug in the explosive-bolt fittings. During assembly and checkout of the two fin-stabilized warheads, it was necessary to replace six defective jack plugs; of the two remaining plugs, continuity on one was difficult to obtain on several checks. Continuity appeared to be established at last, and final checks were completed prior to the flight test.

The cluster which was released by FSW 87A-4 opened and dispersed 223 of the E54R6 munitions, leaving 83 behind in the one cluster adapter half. Of the 216 munitions which were recovered, 198 or 91.7% functioned normally. As to those which failed to disperse, there is no way of knowing whether this failure was a result of the premature opening or was due to an inherent flaw in the system.

The Martin representatives believed that the failure to separate was caused by an area of negative pressure over the forward face of the center section bulkhead. To overcome this, a pitot tube was mounted on the crown of the nose to introduce ram air internally and create a positive pressure on the bulkhead. In addition, seals were applied at the splice station and the trunnion fittings to prevent the loss of the pressure. With this modification it was believed that the separation problem would be solved and, also, that the premature breakup, which Martin personnel believed was a result of structural damage caused when the nose flipped over, would not recur.

The problem of partial dispersion of the munitions had been anticipated from the start, and a relatively simple solution was apparent from the high-speed movie taken of the static tests of the nose casing. These movies showed that the nose was cut cleanly and that the two halves had separated with considerable force. It was felt that this force could be utilized to insure positive separation by simply tying the adapter half to the nose casing. When the partial results of FSW 87A-4 test were obtained, it was decided that this change should be incorporated for the next tests. This was done by adding four clevises to each adapter half, one clevis in each corner near the parting line. From these clevises cables were extended in pairs from the forward end of the adapter half, through a cable clamp mounted on the trunnion fitting, and thence aft to the clevises on the aft end of the adapter.

The changes described were scheduled for incorporation on FSW 87A-2 and FSW 87A-5, which had previously been reworked after the premature bolt-firing incident. During this period a meeting was held at Wright Air Development Center on 8 January 1954, in which the Air Force requested the Glenn L. Martin Co. to submit a cost estimate and a proposed program for conducting the fin-stabilized warhead tests. The purpose of this request was to provide proper support to the Chemical Corps and to place responsibility for the performance of the fin-stabilized test vehicle with the Martin Company in the same way that the Martin Co. had responsibility for the performance of the B-61A missile. Essentially, the Chemical Corps would furnish all Government equipment and clusters for which the Corps would normally be responsible. The Martin Co. would have responsibility for all other materiel and would also modify, assemble, install, and otherwise get the fin-stabilized warhead ready for test up to the point of takeoff of the carrier aircraft. After the test, Chemical Corps personnel would be responsible for evaluating the pattern and the individual munition.

d. Test of FSW 87A-2 and FSW 87A-5.

To facilitate the program, the Air Force gave the Martin Co. a letter of intent enabling the company to begin operations immediately. Martin personnel proposed that both FSW 87A-2 and FSW 87A-5 be fully telemetered. The two nose casings were shipped to Holloman Air Development Center from Walker Air Force Base to effect the necessary changes and installations. The reworked noses were reshipped to Walker Air Force Base and assembled to the afterbodies. On these the cables which tied the adapter halves to the nose casing were also incorporated (12).

During the rework period at Holloman ADC the remains of FSW 87A-6 were excavated (figs. 37 and 38) and sifted carefully for the vital components. All of the bolt fittings were recovered, three showing normal functioning and the fourth intact with the blasting cap still in place. This fitting is shown in fig. 39 as it was found. This seemed to be the evidence needed to prove that the jack plug connection in the fitting was unreliable. On the strength of this find, the jack plugs were taken out and terminal strips were installed in their place. This would insure positive connections and would also permit checkouts to be made which removed all doubt as to its reliability.

In view of the fact that one of two delay detonators installed on FSW 87A-4 had failed, it was decided to abandon this installation in favor of commercial delay electric blasting caps with proved reliability. The sum of these changes covered all of the possible sources of error, and it was felt that chances for a successful test were excellent.

The assembly of FSW 87A-2 and FSW 87A-5 was routine; all preflight checks were satisfactorily accomplished. The telemetry was installed by Martin personnel and again, preflight checks were satisfactory. T1404 fuzes were also installed in these two missiles in a manner identical with that used on FSW 87A-4 and FSW 87A-6.

FSW 87A-2 was transported to the aircraft and hoisted into position in the forward bomb bay. Some difficulty was encountered in aligning the vehicle to bring the drag-pin hole into position with the drag

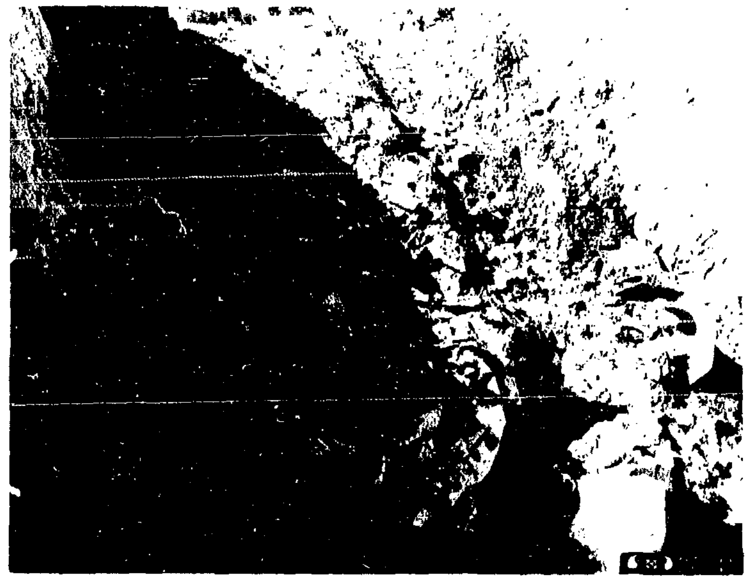

FIGURE 37

REMAINS OF FSW 87A-6 AFTER EXCAVATION

FIGURE 38

GENERAL VIEW OF EXCAVATION REQUIRED TO RECOVER INTACT
FSW 87A-6 EXPLOSIVE-BOLT FITTING

FIGURE 39

EXPLOSIVE-BOLT FITTING FROM FSW 87A-6 WITH UNSEVERED BOLT IN PLACE pin. Before the bomb rack slings could be attached around the vehicle, a short cable link between the C-10 hoist hook and the triangular ring in the canvas hoist sling failed, due to fatigue. The vehicle fell approximately 7 ft. to the ramp, causing extensive damage to the skin and all frames in the nose plus the first two frames in the center section. The two lower fins also were crushed, and the upper left fin suffered punctures in collision with the structure in the aft section of the bomb bay. Views of this damage are shown in figs. 40 through 45.

The cluster suffered no external damage and was eventually returned to these Laboratories for disassembly. None of the adapter components showed any effect from the fall, and the E54R6 munitions were still safe and undamaged. The T1404 fuze was also removed in a safe and serviceable condition.

Loading of FSW 87A-5 was delayed, pending a revision and acceptance of the loading procedure. The equipment was reexamined, and modifications were made which provided positive connections at all points in the hoisting equipment. This modification was acceptable to personnel of the 6th Bomb Wing for a single operation only in order that the mission could be performed. FSW 87A-5 was then installed in the aircraft with no further incident.

The missile was launched from an altitude of 35,499 ft. with a velocity of 490 f.p.s. on a true heading of 253°. Release was normal, and warhead separation occurred at 35.90 sec. Opening of the warhead was also normal, and recovery was effected approximately 1,600 ft. beyond the target on the same heading. Of 306 unit munitions, 298 were recovered for a percentage of 97.4%, while performance of the munitions was exceptionally good with 280 functioning normally for a factor of 94%. The pattern was nearly circular, covering a total area of approximately 89,000 sq.yd., a portion of which can be seen in figs. 46 and 47.

The T1404 fuze was recovered with its recorder, both intact and undamaged. The recorder indicated a 29-1/2-sec. arming time for one side of the fuze and 30 sec. for the other. The detonator circuit on one side was closed in 34 sec., while on the other side there was no indication of the operation of the detonator circuit. The malfunction was traced to a defective contact in the rotor circuit, which was to be corrected on all future models.

The telemetering functioned perfectly throughout and provided the desired information. An evaluation of these data, particularly the pressure data on both sides of the center section, was prepared by the Glenn L. Martin Co., but the data have not yet been forwarded to these Laboratories. Consequently, no conclusions can be drawn as to the merits of incorporating the pitot tube and the various seals in the nose section.

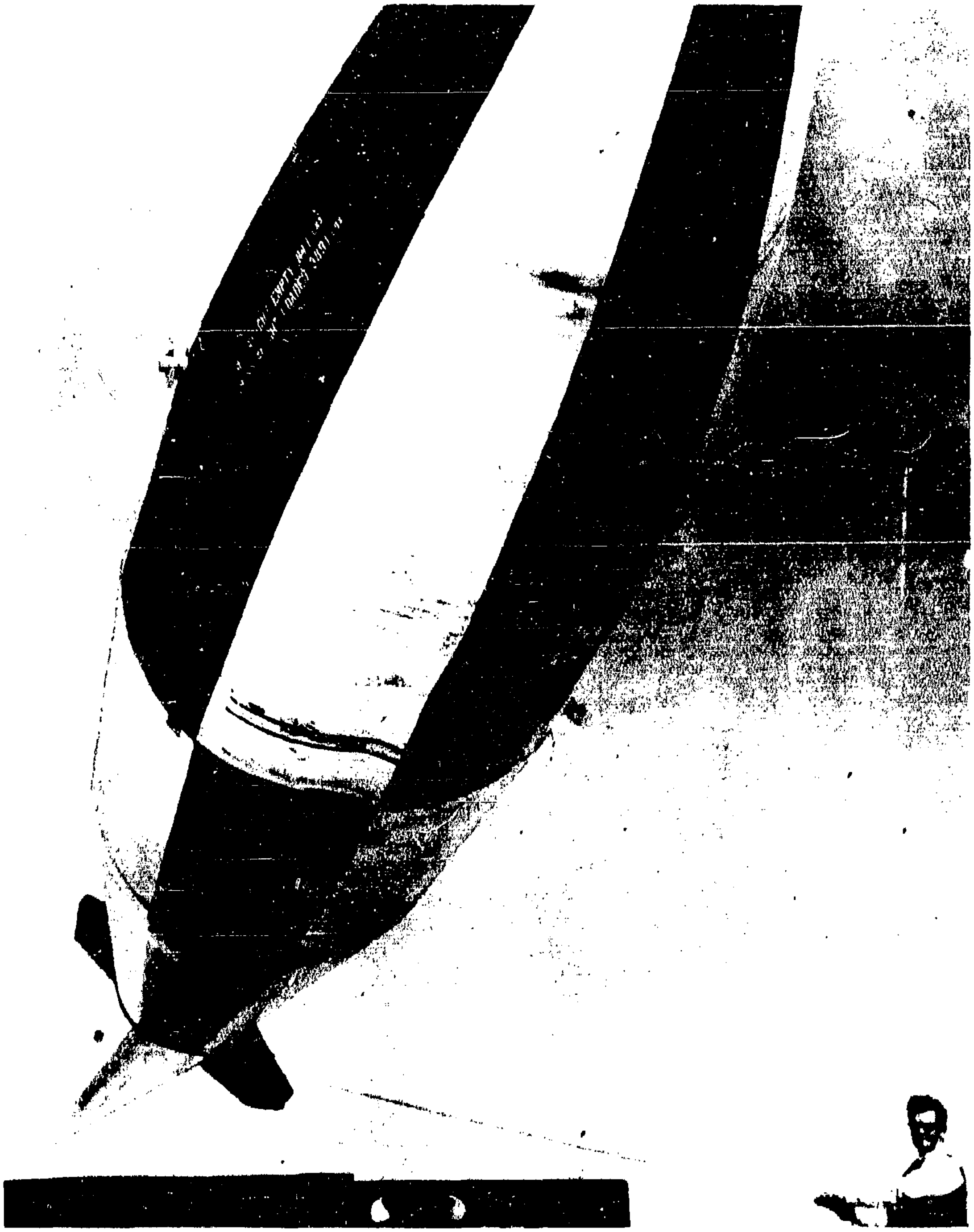

FIGURE 40

UNDERSIDE OF FSW 87A-2 SHOWING DAMAGE AFTER FALL FROM BOMB BAY

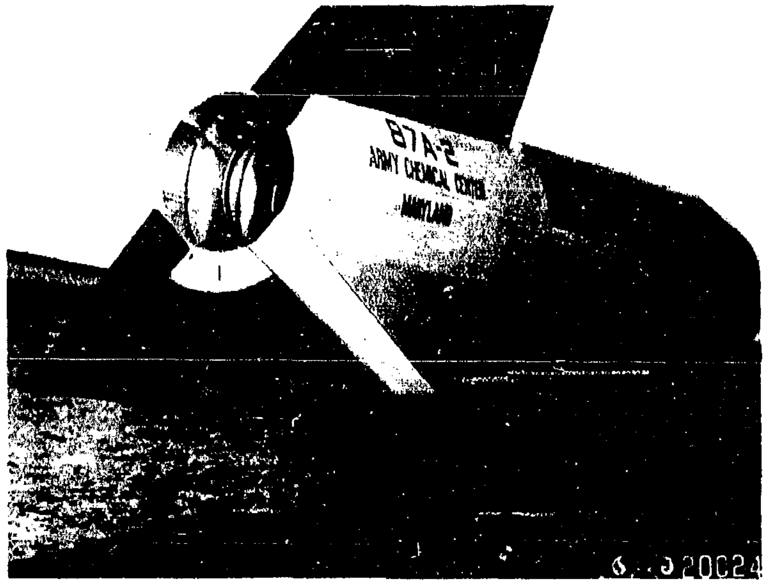

FIGURE 41

TAIL ASSEMBLY OF FSW 87A-2 SHOWING DAMAGED FINS

FIGURE 42

VIEW OF DAMAGED WARHEAD FROM FSW 87A-2 SHOWING CLUSTER IN PLACE INTACT

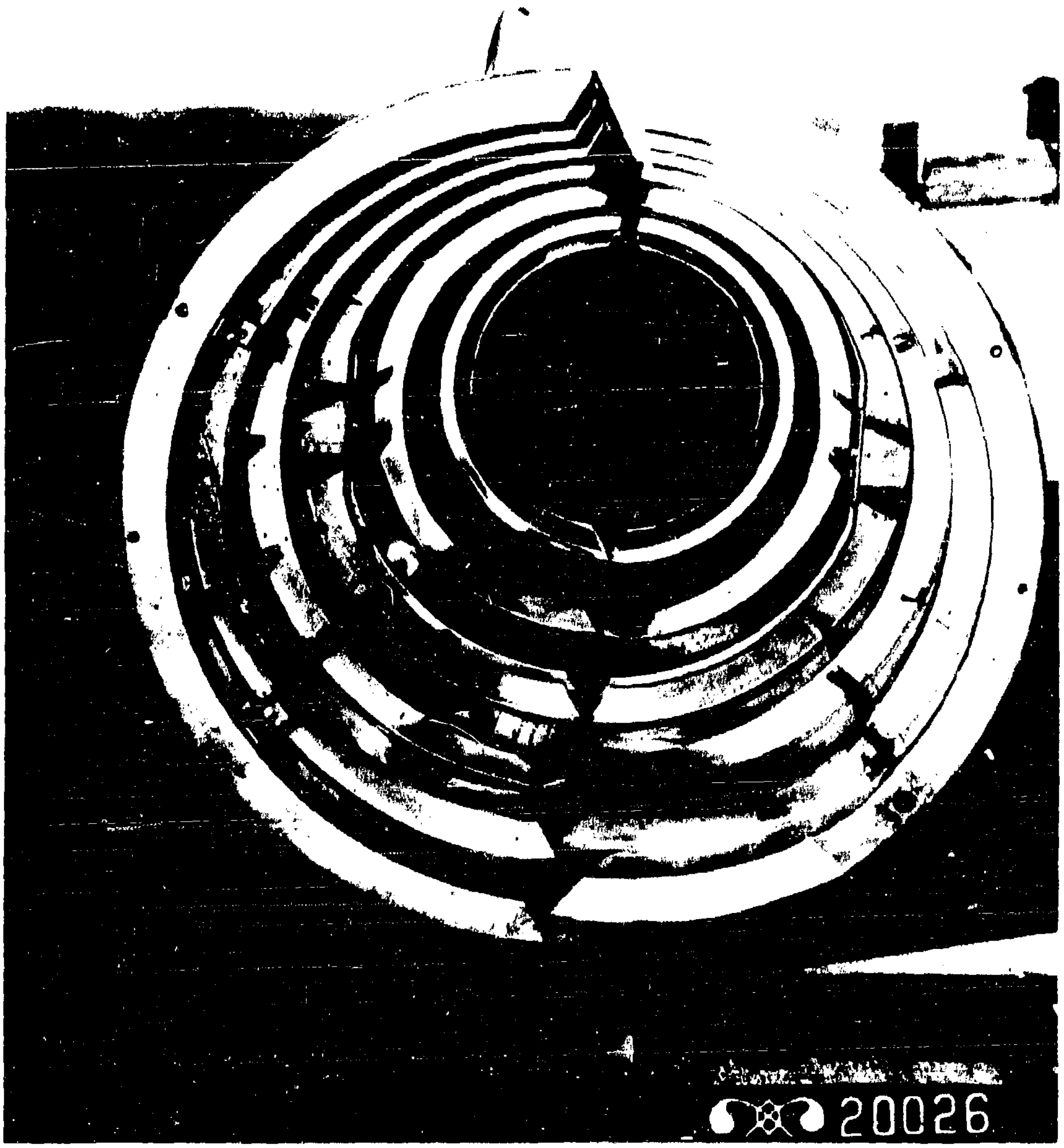

FIGURE 43

NOSE CASING FROM FSW 87A-2 SHOWING EXTENSIVE DAMAGE TO ALL FRAMES

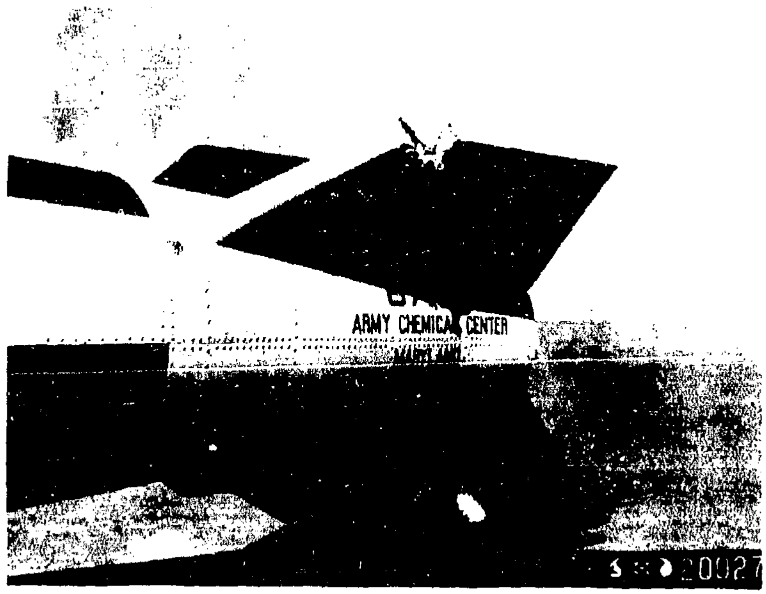

FIGURE 44

FSW 87A-2 TAIL ASSEMBLY SHOWING DAMAGED FINS

FIGURE 45

DAMAGED CENTER SECTION OF FSW 87A-2

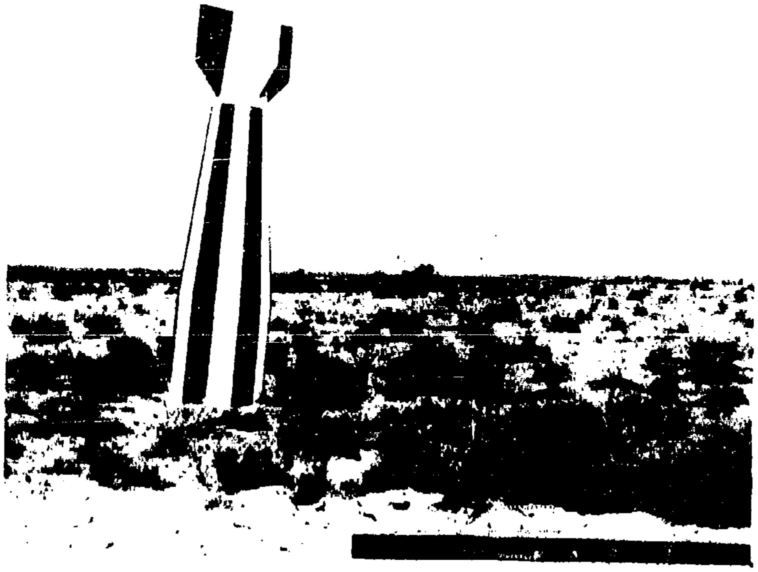

FIGURE 46

TAIL ASSEMBLY OF FSW 87A-5 AFTER IMPACT SHOWING E54R6 MUNITIONS IN TARGET AREA

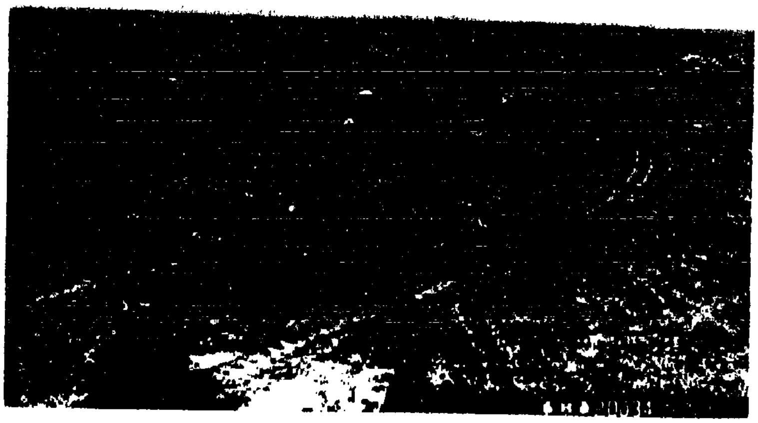

FIGURE 47

VIEW OF TARGET AREA SHOWING E54R6 MUNITIONS DISPERSED FROM FSW 87A-5

Results of this test seemed to bear out the wisdom of the modifications performed, and no particular difficulty was anticipated for the remainder of the test program. Normal opening of the nose by the primacord system is illustrated by figs. 48 and 49.

As mentioned before, for the sake of expediency the modified loading equipment was approved only for the one operation. An entirely new system was required for future operations which would comply with the ground safety rules of Strategic Air Command. The simplest and quickest method of developing a new loading procedure was planned around an obsolete bomb-loading pit located on the ramp at Walker Air Force Base. An adapter cradle was designed and fabricated which would seat and lock on the bed of the hydraulic lift and also would physically tie the missile to the cradle. This arrangement satisfied the personnel of the 6th Bomb Wing, and plans were made to go ahead with the test program.

e. Tests of FSW 87A-1 and FSW 87A-7.

FSW 87A-1 and FSW 87A-7 were modifed to incorporate all of the changes successfully tried on FSW 87A-5. FSW 87A-7 was taken from the final engineering phase of the program to replace FSW 87A-2, which was surveyed as unusable. Only one additional change was incorporated in this test, and that was the inclusion of an additional safety switch in the nose which, when open, grounded the delay electric blasting caps which detonate the primacord. This addition insured complete safety during the assembly of the nose. After the attachment of the nose to the center section, the safety wire was removed and the blasting cap was then grounded by the master switch in the center section. This circuit is illustrated in fig. 23 and represents the ultimate in safety without any sacrifice of reliability.

FSW 87A-7 and FSW 87A-1 were released under weather conditions which rendered the Askania cameras useless. The decision was made to go ahead with the test in spite of the weather because of the prospect of an indefinite delay and also because these two vehicles represented the last drops to be made, in view of the fact that the Air Force directive canceled any further effort on the program.

FSW 87A-7 was set to function 5,000 ft. above the target, and separation of the warhead was normal. However, opening of the nose apparently was accomplished in the same manner as for FSW 87A-4. Separation of the nose could be seen from the observation point, and an explosion, such as would be expected from primacord, was heard. Nevertheless, the remains showed no indication of severance by primacord; in fact, large segments of primacord were found with the nose fragments (figs. 50 and 51).

The tumbling motion of the nose apparently caused the tie-down cables to fail before they could separate the adapter halves, with the

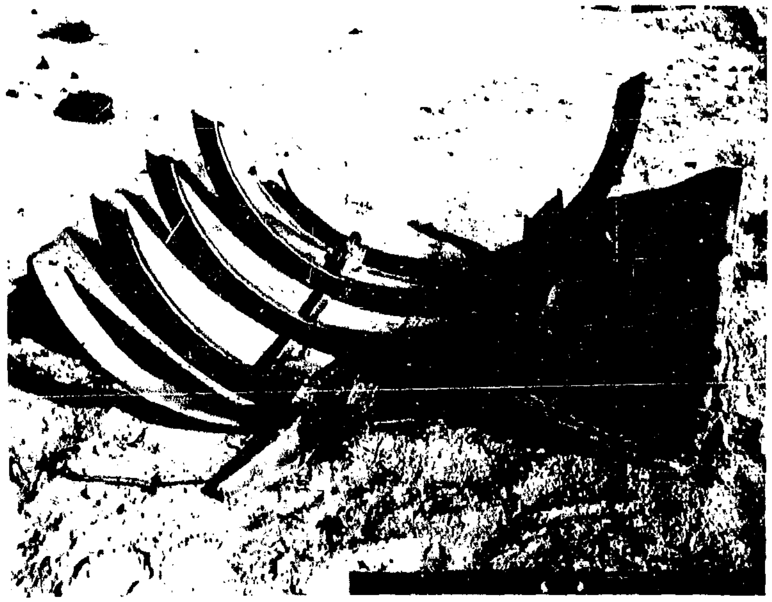

FIGURE 48

PORTION OF RIGHT SIDE OF FSW 87A-5 NOSE CASING SHOWING PROPER CUTTING BY PRIMACORD

FIGURE 49

VIEW OF FSW 87A-5 NOSE CONE SEVERED BY PRIMACORD

FIGURE 50

PORTIONS OF FSW 87A-7 NOSE CASING SHOWING UNDETONATED PRIMACORD

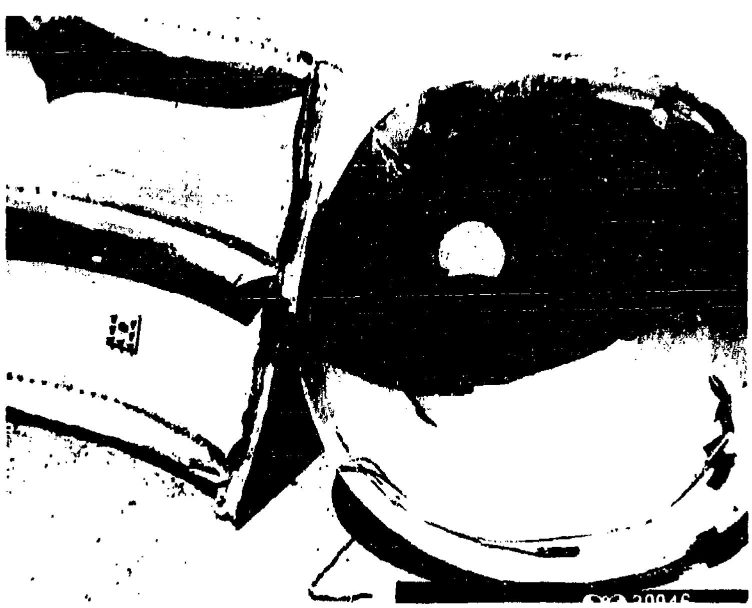

FIGURE 51

FSW 87A-7 NOSE CONE AND PORTION OF CROWN SHOWING UNDETONATED PRIMACORD result that 90 bombs came down inside of one adapter half (fig. 52). Of those which did leave the adapter, 184 were recovered, and 153 of these functioned normally. It is believed that the bulk of those still missing were buried below the point where the adapter half impacted.

FSW 87A-1 was timed to open at 10,000 ft. above the target, and separation was again normal. As before, an explosion could be heard from the primacord detonation. In this instance, the nose pieces indicated that opening of the warhead was normal (fig. 53), and ejection of the munitions occurred as planned. A recovery of 296 munitions was effected, with 246 of the total functioning normally. An excessive number of fuze failures and failure of parachutes to unfurl was counted in the total. Reason for these failures was not determined.

These last two tests concluded the entire program for development of chemical warheads for the MATADOR missile, since the Air Force directive canceled all future effort for the MATADOR.

Because of the advanced state of development of the shipping container, the Air Force agreed to permit continuation of its development within the limits of the funds on hand.

Permission was also granted by the Air Force to procure a quantity of T1404 fuzes to be used in conjunction with the unexpended fin-stabilized warheads. These warheads have been slated for use in the basic project for investigation of new munitions and methods for dispersing these munitions.

V. DISCUSSION.

A project of such scope as the chemical warhead for the MATADOR requires considerable thought and planning at its inception and sufficient time for its proper execution. This was not entirely possible in this case, as by the time that the MATADOR had progressed from the prototype stage (YB-61) to the B-61A production version, the emphasis had been concentrated on the urgency of delivering a complete weapons system in the shortest possible time.

The transition from the YB-61 nose casing had only minor effects on the development of other types of warheads since the original packages required few physical changes and could be carried equally well by the B-61A. This was not the case with the chemical warheads where the redesign of the nose casing rendered all prior chemical warhead work obsolete. In addition to beginning anew on the actual chemical warhead, a complete new set of supporting equipment was required, including a new fuzing system. All of this imposed a heavy burden at a time when the local supporting facilities were heavily taxed because of the national emergency in Korea. Consequently

FIGURE 52

FSW 87A-7 CLUSTER ADAPTER HALF AND MUNITIONS WHICH FAILED TO DISPERSE

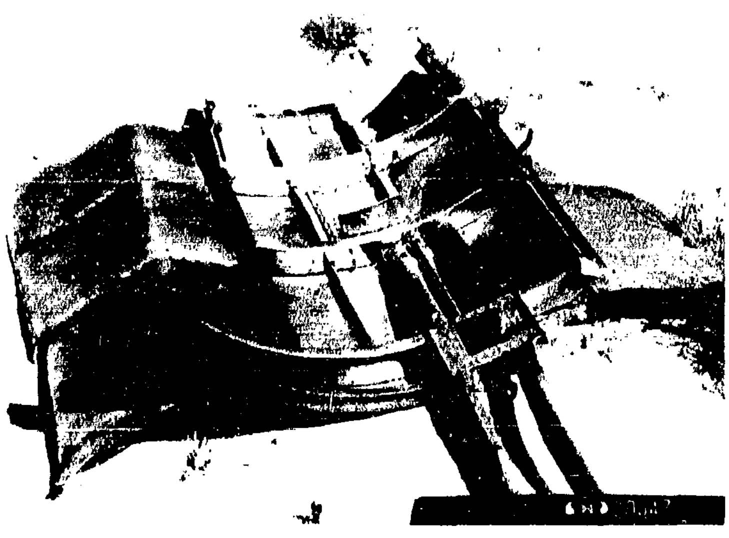

FIGURE 53

PORTION OF LEFT SIDE OF FSW 87A-1 NOSE CASING SHOWING PROPER CUTTING BY PRIMACORD much of the work was of necessity placed on a contract basis. This again consumed valuable time while facilities were being investigated and bids were being considered.

On the whole, the warhead program progressed smoothly and fairly rapidly, mainly because much of the design work was effectively coordinated with the various agencies so that the designs could be frozen at an early stage. This was also true of the T1404 fuze developed by Diamond Ordnance Fuze Laboratory. Although much time was lost before Diamond Ordnance Fuze Laboratory was called in, progress from that time on was rapid and very satisfactory.

The E54 cluster adapter, while it is sufficiently strong could still be modified to reduce the gross weight with no critical loss of strength. The working parts of the latching mechanism could also be improved to provide a positive lock in either the open or closed position without the necessity for extremely close tolerances on the components. The liner problem was never completely solved, but the material selected for use through the test phase appeared to be satisfactory on a short-term basis. A more thorough investigation might have shown undesirable qualities under various storage conditions or possibly imcompatibility with agents and materials of construction.

As noted earlier, the T1404 fuze was completely in the hands of Diamond Ordnance Fuze Laboratories, and no attempt will be made here to evaluate the fuze beyond the results already reported by DOFL, except to note that the fuze complied with the military characteristics in so far as the development testing had progressed.

The B-61A nose casing, which was designed for the chemical warheads, was demonstrated to be feasible and could, with minor changes, be considered a satisfactory interim system for carrying and dispersing the unit munitions in the warhead. The B-61A, up to this time, is the only missile in which specific provisions have been made for carrying chemical warheads and the design work on the nose was accomplished with no other consideration. The design and development of the nose offers a good example of the quality which can be achieved when the missile contractor and the warhead agency work together on even terms with a high-degree of coordination and cooperation and, equally important, with the complete approval and cooperation of the USAF Project Office.

The development of the arming and monitoring system further demonstrated the effect of full participation and coordination of the various developing agencies having a working interest in the MATADOR. The system as it now stands is capable of fulfilling all requirements for the several warheads and, in addition, meets all specifications for ground safety, reliability, and in-flight safety. From a production standpoint the system also complies with the missile philosophy of simplification, since the individual requirements for specific warheads were incorporated into one integrated system, rather than supplied as a group of individual systems, only one of which would be applicable to any given flight.

Squadron support equipment is still another example of integration. Wherever a common need was noted, the equipment was designed to accommodate readily those components having similar requirements. The warhead trailer is a case in point, where the design of the trailer was originally directed only toward carrying the nuclear warhead, but in subsequent coordination and redesign the trailer was readily adapted to any of the six warheads with little change from the original version.

The over-all system which eventually evolved could be considered a good workable system, but wide open for improvement. Because of the time limitation no elaboration of the present system was possible, nor was it possible to investigate other principles and methods which might have resulted in a much more effective warhead. As early as 6 mo. after the development began, the Air Force emphasized the urgency of the program and requested that any feasible design be frozen. In other words these Laboratories were not to strive for maximum dispersion of the unit munitions (13). This immediately limited the effort and resulted in the present system which indicates that the toxic coverage attainable is on the order of 50% of the theoretical coverage based on the accepted and rather severe criteria in effect at the time.

The study was valuable in emphasizing the restrictions placed on any warhead system by an inflexible target and contamination dosage criterion. No distinction was made in the mission of the missiles, e.g. tactical or strategic, nor was there any consideration for the proximity of the target to the main line of resistance. It is now an established fact that the dosage required to cause either death or incapacitation varies directly with the physical and mental condition of personnel subject to attack by a toxic warhead. This, in turn, is related to the type of activity in which an individual is engaged, ranging from troops under the stress of combat to more or less complacent workers located at great distances from zones of combat. The conditions for attack are further affected by the high degree of readiness in combat areas, ranging down to a low order of discipline among civilian populations instilled with a sense of security brought on by their remoteness from the areas of conflict. Thus, the effectiveness of any toxic warhead cannot be measured against one fixed standard. All of the factors mentioned and more must be considered to arrive at a realistic measure of the value of the warhead.

The fin-stabilized test vehicle which was developed for use in the test program in lieu of B-61A missiles is an excellent method for testing warhead systems at speeds below Mach 1. The data obtained from the free-flight tests confirmed the reproducibility of the trajectory and velocities within very narrow limits. The low cost of producing the vehicles and simplicity of supporting equipment are also factors of considerable importance. Finally, the use of such a vehicle offers considerable freedom of movement in planning and executing a test program.

Without exception, the programming of warhead tests in conjunction with a complete guided missile restricts the test program to the missile test facility, which is not always suitable for warhead testing. If the warhead test program can be separated from the missile test program, schedules may be established which can keep pace with warhead development and not be affected by missile schedules or delays in executing the scheduled flights. Conversely, the missile test program will not then be delayed because of any slippage in the warhead program. Furthermore, the choice of facilities for assembly, storage, and flight testing would be greatly expanded by this separation of warhead and missile during the test phases.

The data obtained from the series of fin-stabilized warhead tests are considered to be representative of results which would be obtained from flights on B-61A missiles. This opinion is based solely on theoretical performance calculations for the missile, but missile performance up to the dump point has so far proved the accuracy of the calculations. From the dump point to the target the data for the missile are not very informative due, primarily, to the tendency of the missile to break up somewhere along the terminal dive path. Again, from the evidence, data based on theoretical missile performance in the terminal dive, the fin-stabilized warhead functioned within the design value of 3% error.

Some of the modifications made to insure warhead separation from the fin-stabilized afterbody are peculiar to the test vehicle because of its symmetrical shape and would not be required for the missile version. It has already been shown that the sudden shift in the center of gravity of the missile afterbody at the moment of bolt detonation causes a rapid stall, which insures warhead separation and also prevents interference of the afterbody with the unit munitions.

Range instrumentation at Holloman ADC also played a vital part in the results of the test program. The excellent Askania coverage provided data which gave a full picture of the drops, either from time of release to warhead separation, or to the target area in the case of those which failed to function. The Askania coverage on the last two drops was canceled because of unfavorable meteorological conditions at drop time. However, the tests would not have been conducted without Askania coverage if the project had had any possibility of continuing. As it was, it was felt that enough data had been obtained from prior drops to prove the reproducibility of the trajectory. The velocity and position data available immediately from the radar plotting boards would provide reasonably complete information.

One matter which should be investigated is the problem of determining the exact moment of release from the carrier aircraft or, even more precisely, the moment at which the timers are actuated. Zero time on the tests was usually an arbitrary point, selected by examination of the processed Askania film, and there was no possible way of pinpointing the exact moment of release. One method of establishing zero time would be to utilize a very high candlepower light source, which would light up at the moment the timers are actuated. Another possiblity would be to utilize radar bombing in conjunction with a continuous time-tone signal which cuts off at the moment of release. The latter method is not as exact as the former, because it provides data on the moment of release only and not on the moment at which the timers are actuated.

From data recorded in appendix G, it would appear at first glance that the bomb pattern is not reproducible, but further examination shows that the patterns for FSW 87A-1 and FSW 87A-5 are nearly identical. Appendix D shows that the conditions of flight for these two warheads were also very similar. Moreover, the two warheads performed at opening as planned, thus indicating that performance may be duplicated.

For FSW 87A-4 and FSW 87A-7, the variation in results can be attributed to two factors. In the first place, each of these two warheads opened prematurely after separation from the afterbody and caused the individual munitions (those that did come out) to trail out of the adapter. Secondly, FSW 87A-7 had 190 lb. of ballast in the cluster which was not included in FSW 87A-4. This additional weight increased the velocity at opening and also a greater dive angle at the time of opening. It is believed that these variations from a normal opening were enough to alter the patterns as shown in appendix G.

Thus, it would appear that an efficient opening system places a penalty on the size of pattern which can be obtained. The obvious answer is to work backward from this point and, while retaining the efficient opening, attempt to increase the time interval over which the individual munitions are released. Only in this way can an effective area coverage be achieved; but, even with this, it can be assumed that the pattern will be characteristically long and narrow.

Referring to the area coverage of FSW 87A-1, for example, an increase of 50% in the pattern radius would be necessary to achieve the desired area coverage. How this can be accomplished with the existing system is not known, nor does it now appear to be possible. If, on the other hand, the elliptical pattern is considered, it would require no more than a 19% increase along the major axis to achieve the desired area coverage, basing this conclusion on the performance of FSW 87A-4.

It would seem then that the slow release of the munitions for an elliptical pattern would be the easiest way to bring the system up to at least its minimum capability, that is, the coverage resulting from a Gaussian distribution.

VI. CONCLUSIONS.

1. A complete gas warhead system for the B-61A missile has been designed and partially tested. However, indications are that the toxic coverage attained falls short by approximately 50% of the potential capability of a warhead of this design.

2. A new approach to the problem incorporating some type of dispersion mechanism or a new self-dispersing munition would be necessary to achieve a better coverage of the target with agent.

3. The large errors which exist in the terminal dive phase of the B-61A missile at the present time make it questionable whether any reasonable degree of accuracy can be achieved utilizing the E54R6 bomblet.

VII. RECOMMENDATIONS.

None, since the project has been canceled, and no further effort will be applied.

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APPENDIX A

FREE-FLIGHT TEST PROCEDURE, B-61A FIN-STABILIZED WARHEAD*

The target used is shown in fig. 54. In fig. 55 the fin-stabilized warhead is shown as it left the aircraft.

I. Test Conditions

A. Aircraft: B-36F

B. Target: Tarzon (Holloman ADC)

C. Release altitude: 35,000 ft. (MSL)

D. True air speed: 350 m.p.h.

**E. Fuze setting:

1. Warhead separation

2. Cluster release

F. Direction of drop: 240° Magnetic (WSW)
253° True

G. Range bombing system: Radar guidance

H. Special instructions:

Unless verbally changed: Guide the drop aircraft in a left-hand pattern, final heading 240° magnetic. Execute drop point will be 17,070 ft. short of Tarzon target. Count-down will be given over VHF to aircraft at one-minute intervals through X-2 minutes, then 90, 60, 45, 30, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 second drop. Aircraft call sign: "Red Dog".

I. Communications:

1. Intercom: All stations listed on main intercom
Baker 11 on monitor (if manned)

2. VHF: 150.66 mc. primary at X-ray-1 and King-1
149.22 mc. secondary at Queen-1. Tunable receiver standing by on monitor amplifier at King-1

* This appendix is a copy of a manual prepared for use with the B-61A fin-stabilized warhead.

**Subject to variations based on data from previous test.

FIGURE 54

VIEW OF TARZON TARGET FROM 35,000 FT.

FIGURE 55

FALL-AWAY OF FSW 87A-3 FROM B-36F AIRCRAFT

II. Instrumentation

A. Askanias: 4 Stations (B & W-5 f.p.s.)

B. Servo-tracked camera: 1 Station (B & W-72 f.p.s.)

C. Hand-panned cameras: 2 Stations (C & B & W-16 f.p.s. & 72 f.p.s.)

D. Radar: X-ray-1 X-ray-2

1. Plotting board: Single Pen Double Pen

III. Data.

A. Date of test:

B. Time of test:

C. Aircraft type and number:

D. Aircraft altitude:

E. Aircraft velocity:

F. Aircraft azimuth:

G. Release altitude:

H. Warhead separation altitude:

I. Cluster opening altitude:

J. Time from release to warhead separation:

K. Time from warhead separation to cluster opening:

L. Aircraft position data at time of release with reference to "Tarzon" target or N.A.A. tower:

M. Missile position data at time of warhead separation with reference to "Tarzon" target or N.A.A. tower:

N. Warhead position data at time of cluster opening with reference to "Tarzon" target or N.A.A. tower:

O. Wind and temperature data aloft to release altitude:

P. Bomb Pattern:

1. No. flat landers:

2. No. without parachutes:

3. No. fuze malfunctions:

4. No. delay failures:

5. Cause of delay failures:

6. Photography as deemed necessary (stills):

Q. Target reference to bomb pattern survey station:

IV. Handling and Loading Procedure

A. Bill of material:

1. Fin-stabilized warhead:

a. 87-2000000 Warhead assembly, complete, fin-stabilized warhead

(1) 87-2000001 Nose section assembly, complete

(2) 87-2000003 Center section, fin-stabilized warhead

(3) 87-2000004 Aft section assembly, fin-stabilized warhead

(4) 87-2000005 X-frame assembly, nose bomb support

(5) 87-2000033 Hoist lug

(6) 87-2000034 Explosive bolt

(7) 87-2000018 Special bolt

2. Cluster, E125:

a. Cluster, nonpersistent gas bomb, 3000-lb., E125, in shipping container (1)*

*Indicates number of items.

3. Fuze:

   a. B423-2-510 Guided missile timer assembly (2)

4. Power:

   a. 18-10P Battery, 27 v., Bright Star (2)

   b. D21-765 Battery rack (2)

   c. Safety switch (Microswitch no. BZ-2RM). (2)

5. Explosive Devices:

   a. E81 DuPont U.S. Corps of Engineers elec. blasting cap (4)

   b. No. 2 delay electric blasting cap (2)

   c. Primacord, double strength, 35 ft.

   d. Arming wire, w/Fahnestock clip and switch, 15 ft. (3)

   e. Safety wire, w/Fahnestock clip and swivel, 3 ft. (3)

6. Handling equipment:

   a. 87-2000041 Sling assembly - fin-stabilized warhead

      (1) 87-2000041 Trunnion fittings (2)

      (2) 258E9580-109 Plate (2)

      (3) A623 "Pip" pin (2)

   b. D21-798 Warhead loading stand (1)

   c. D21-852 Cluster handling clamp

   d. A4-15 Sling, wire, canvas, climax, 15 ft. (2)

   e. Crane, heavy equipment, mobile

   f. Joyce-Cridland "Materialift"

   g. "Materialift" adapter cradle

   h. M-5 Bomb trailer

   i. Bomb racks, 43,000-lb.

7. <u>Check-out Equipment</u>:

a. Blasting galvanometer

b. 0 to 50-v. d-c. Voltmeter

8. <u>Miscellaneous tools</u>:

a. No. 1 Phillips screwdriver (2)

b. No. 2 Phillips screwdriver (2)

c. FP-22 Phillips bit no. 2, "Snap-on" 3/8-in. drive (1)

d. K-4 speed handle, "Snap-on" 3/8-in. drive (1)

e. St-012 Phillips offset screwdriver, "Snap-on" no. 1 & 2 bits

f. Standard blade screwdrivers, small and medium (2)

g. SR600-1 torque wrench, Armstrong Armalloy, 1/2-in. drive, 0-600 in.-lb. cap. (1)

h. Socket, 5/8-in., w/1/2-in. drive (2)

i. Socket, 3/4-in., w/1/2-in. drive (2)

j. Pliers, diagonal, side-cutting (2)

k. Hammer, claw, bell face, 16-Oz. (2)

l. Wrench, box, 7/8-in. x 15/16-in. (2)

m. Wrench, box, 9/16-in. x 5/8-in. (2)

n. Wrench, crescent, 10-in. (1)

o. Drill, hand, 1/4-in. capacity (1)

p. Drill, twist, no. 41 (3)

q. Drill, twist, no. 30 (3)

r. Drill, twist, no. 21 (3)

s. Drill, twist, no. 12 (3)

t. Drill, twist, no. F (3)

u. Knife (1)

v. Tape, pressure-sensitive, 250-ft. roll (2)

B. Handling and loading:

1. Select suitable area of hard-surfaced dirt-fill, black top or concrete, approximately 50 ft. x 75 ft.

2. Remove hold-downs from fin-stabilized warhead shipping crate.

3. Disconnect the four explosive bolts, 87-2000034, at station 120, and separate nose and tail to provide approximately 2 feet of working clearance.

4. Install primacord in nose section, 87-000001, in rubber retaining strips (fig. 56).

5. Attach trunnion fittings, 87-2000041-1 at trunnion station 76.594 on nose section assembly, 87-2000001.

6. Remove top half of cluster shipping container (fig. 57).

7. Screw in cluster clamp stops in cluster.

8. Check latches in locked position.

9. Place cluster handling clamp, D21-852, around cluster at c.g. clamp and lock (fig. 58).

10. Place X-frame on warhead loading stand, D21-798.

11. Secure sling plates to clamp trunnions by means of "Pip" pins.

12. Raise cluster from crate and rotate to vertical position (fig. 59).

13. Lower cluster onto warhead loading stand, D21-798, and remove cluster handling clamp, D21-852 (fig. 60).

14. Secure sling plates to nose trunnions by means of "Pip" pins.

15. Raise nose section assembly high enough to clear vertical height of cluster (fig. 61).

16. Secure tie-downs to forward clevises on cluster (4 places) (fig. 61).

17. Lower nose section assembly carefully over cluster (fig. 62).

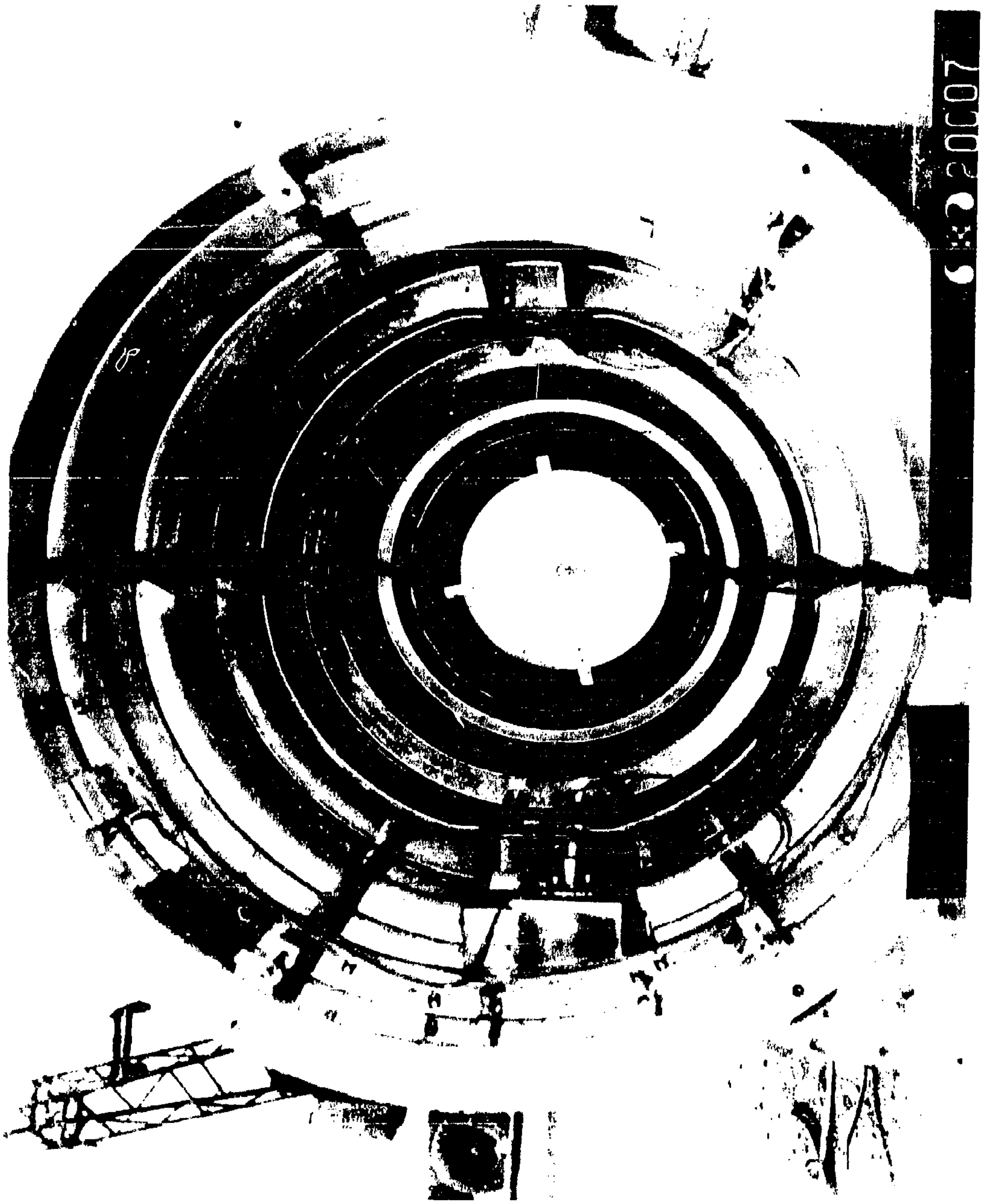


FIGURE 56

INTERIOR VIEW OF NOSE SECTION SHOWING T1404 FUZE BRACKET INSTALLATION AND TELEMETERING ANTENNA INSTALLATION

FIGURE 57

E125 CLUSTER WITH SHIPPING CRATE STRIPPED AWAY

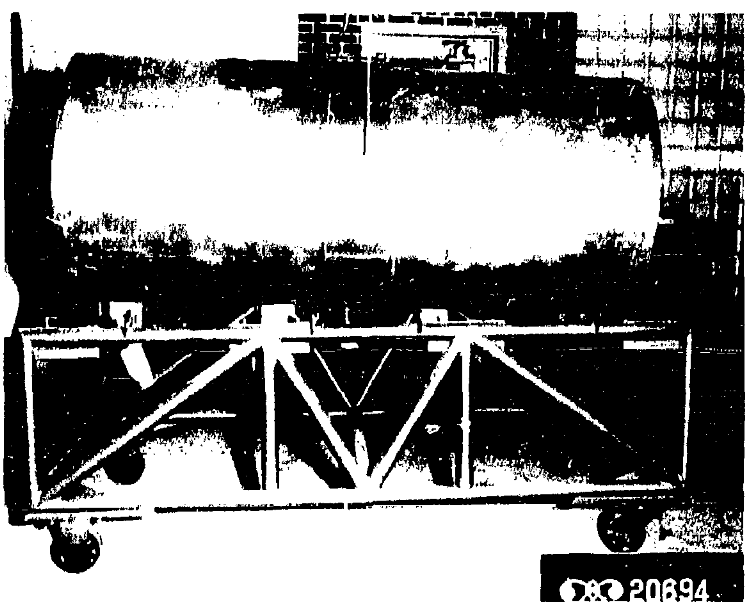


FIGURE 58

VIEW OF E125 CLUSTER WITH CLUSTER HANDLING CLAMP IN PLACE

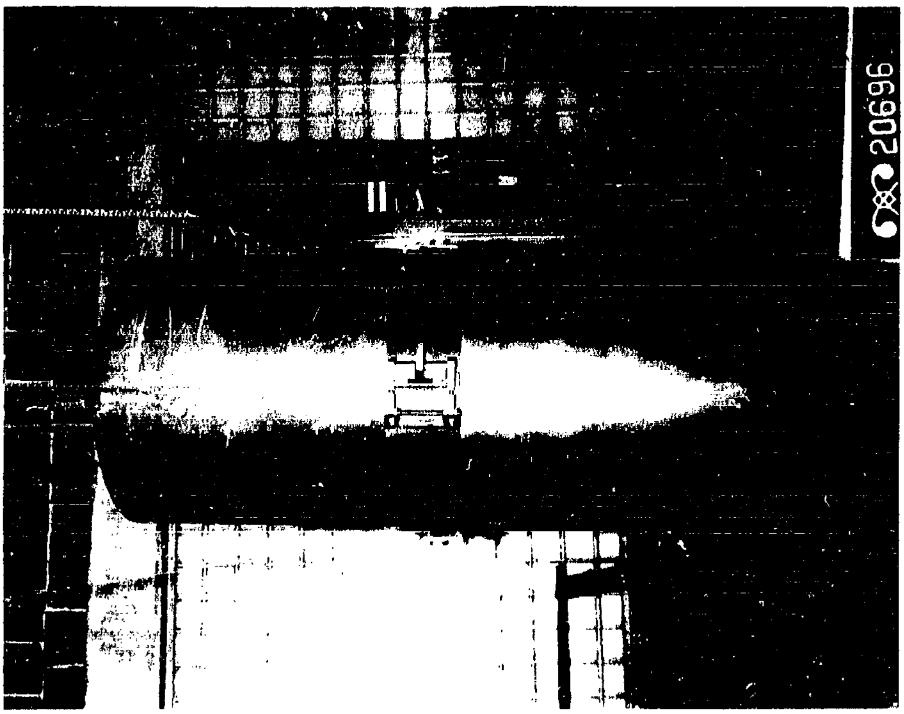


FIGURE 59

VIEW OF E125 CLUSTER RAISED AND ROTATED TO VERTICAL

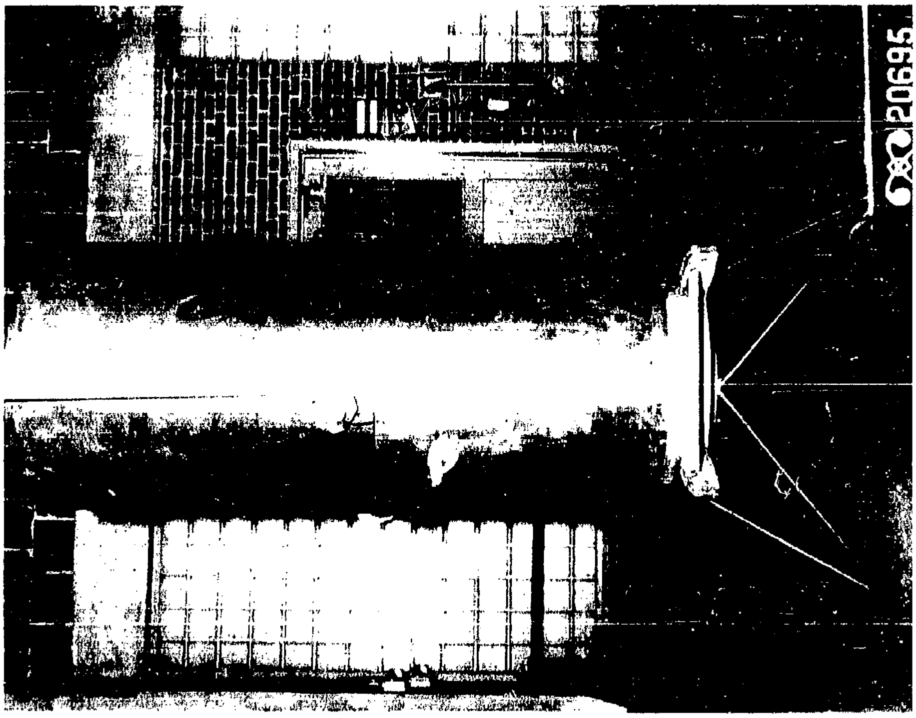


FIGURE 60

E125 CLUSTER LOWERED IN PLACE ON WARHEAD LOADING STAND

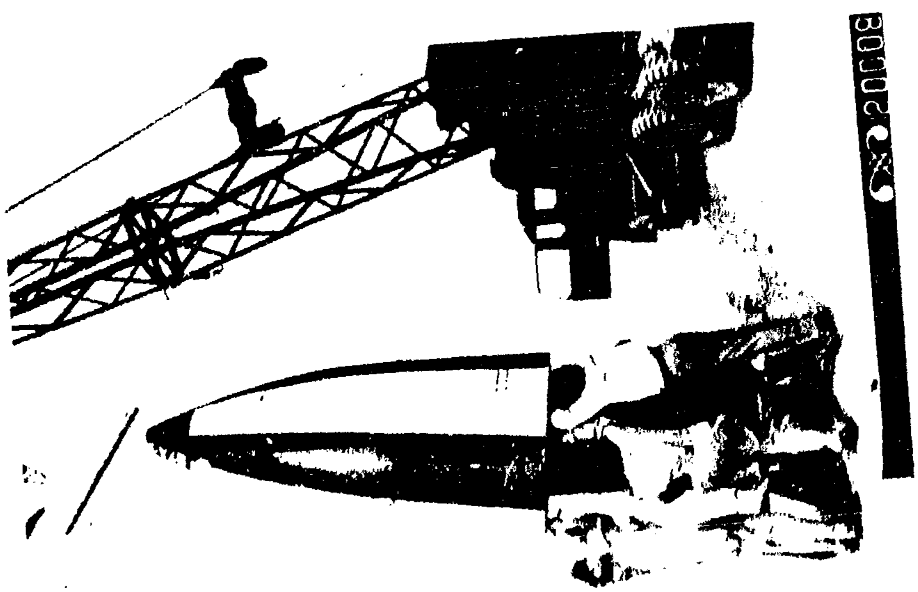


FIGURE 61

LOWERING NOSE SECTION OVER E125 CLUSTER

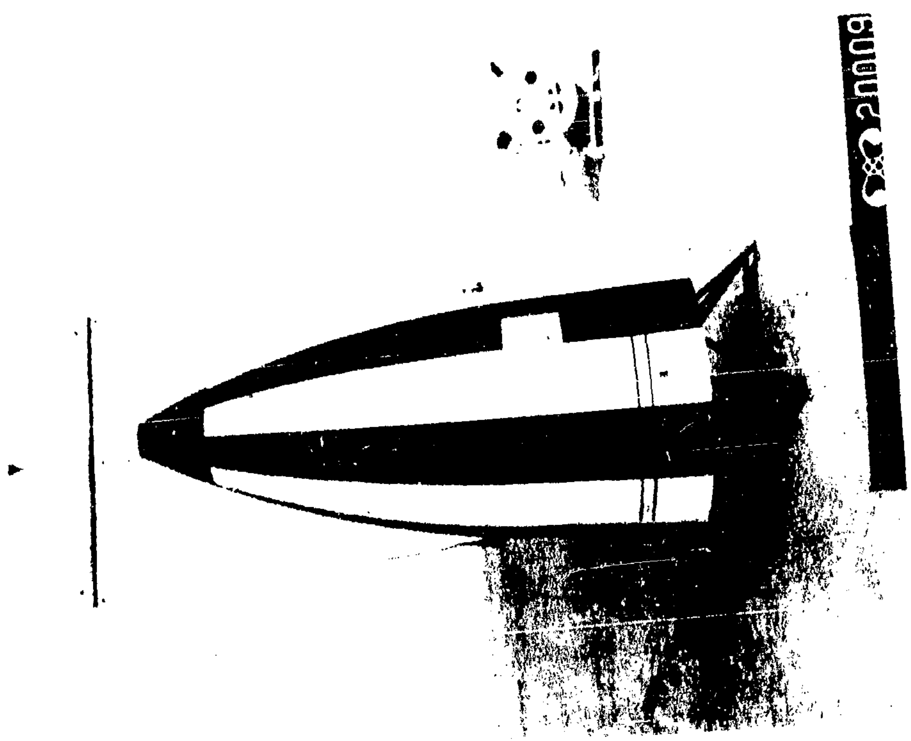


FIGURE 62

ASSEMBLED E6 WARHEAD ON WARHEAD LOADING STAND

18. Secure tie-downs to rear clevises on cluster (4 places).

19. Attach special bolts, 87-2000018, using torque wrench to 280 in.-lb.

20. Attach cable assembly at station 118 by picking up existing AN520 screws. Raise and rotate nose to horizontal (fig. 63).

21. Lower nose section assembly back into shipping crate, leaving sling assembly in place (fig. 64).

22. Insert arming wire in safety switch and attach red streamer.

23. Insert safety wire in delay E.B.C. safety switch.

24. Remove center section door and mount timer assembly, B423-2-510, to frame inside door.

25. Add safety wire to timer through missile crown in place of short wire and attach red streamer.

26. Mount battery racks, D21-765, with batteries, 18-10P, to aft side of center section bulkhead.

27. Check continuity of circuit.

28. Splice delay electric blasting caps to primacord at two places, and check continuity.

29. Connect delay E.B.C.'s to terminal strip in nose.

30. Disengage latches on cluster and lock open.

31. Connect cannon plugs on forward side of bulkhead (2 places).

32. Mate center section to nose section and attach by means of explosive bolts. Check bolts for special washers and under head (figs. 65-66).

33. Insert arming wires in timer assemblies.

34. Plug in power leads to batteries.

35. Check for stray currents.

36. Set two timers and lock.

37. Pull firing-pin safety detents from timers.

38. Secure center section door.

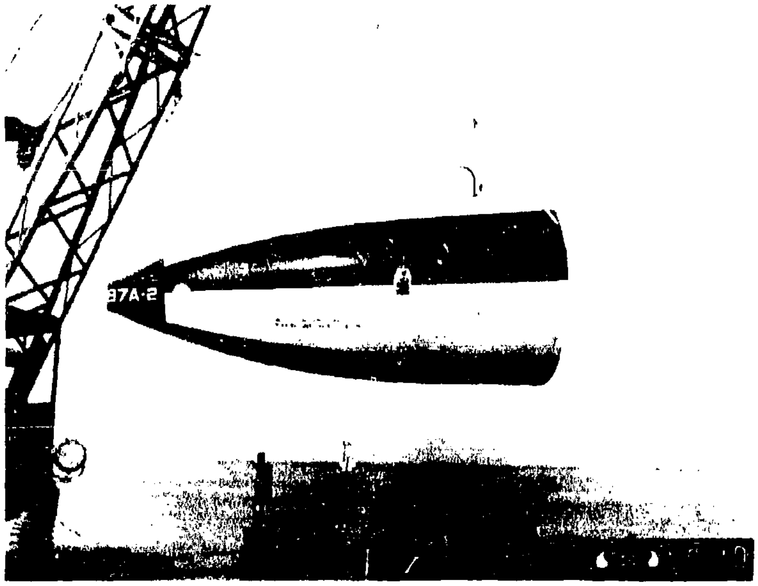


FIGURE 63

E6 WARHEAD RAISED AND ROTATED TO HORIZONTAL ATTITUDE

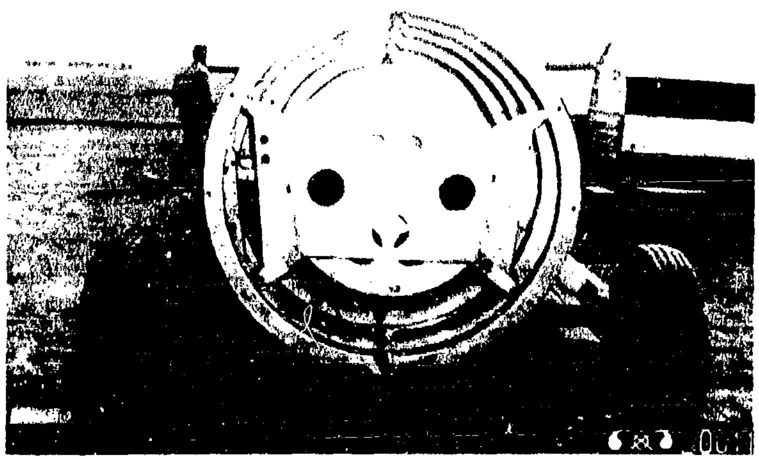


FIGURE 64

VIEW LOOKING FORWARD SHOWING E125 CLUSTER NESTED IN X-FRAME

FIGURE 65

CENTER SECTION SHOWING INTERIM FUZE AND TELEMETERING ELECTRICAL INSTALLATIONS READY FOR ATTACHMENT TO E6 WARHEAD

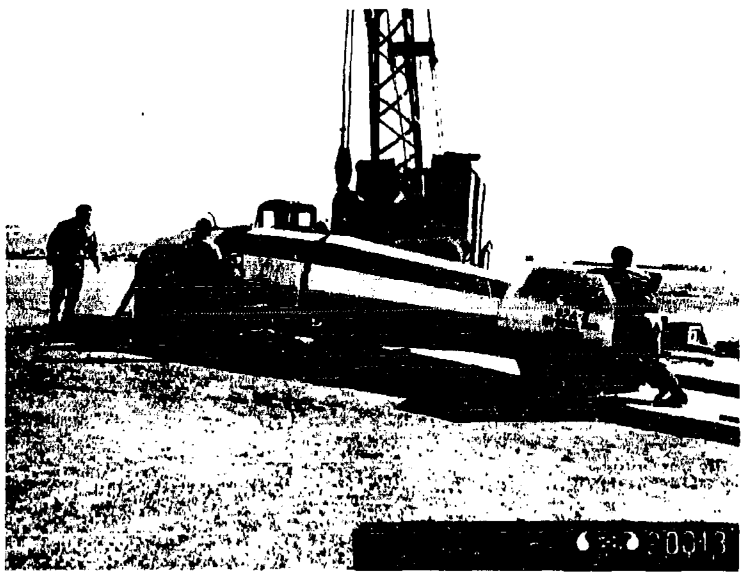


FIGURE 66

METHOD FOR POSITIONING TAIL ASSEMBLY FOR ATTACHMENT TO E6 WARHEAD

39. Install electric blasting caps, E81, in explosive bolts and make connections to terminal strips (fig. 67).

40. Install cover plates over explosive-bolt fittings.

41. Install hoist lug, 87-2000033 on crown at station 120 and attach cable assembly, 87-2000041-29.

42. Raise complete warhead assembly and shift to modified bomb dolly (fig. 68).

43. Tow bomb dolly to "Materialift" loading pit.

44. Raise warhead from trailer and shift to adapter cradle on hydraulic lift.

45. Secure warhead assembly in place by means of tie-downs between warhead trunnions and adapter cradle.

46. Raise warhead into bomb bay and secure by means of 43,000-lb. bomb racks (figs. 69 to 71).

47. Attach safety-switch arming wire and timer arming wire to bomb rack.

48. Pull safety-switch safety wire with red streamers attached (2 places; center section safety switch, nose section delay electric blasting cap safety switch).

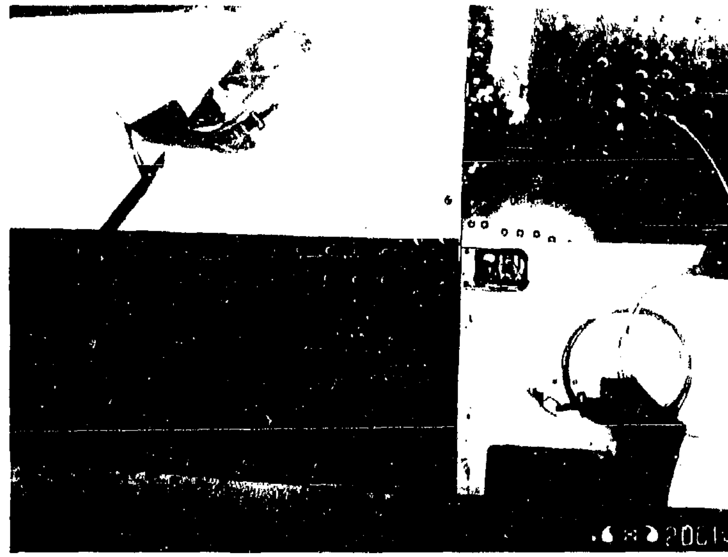


FIGURE 67

BATHTUB FITTING SHOWING EXPLOSIVE BOLT AND TERMINAL-STRIP INSTALLATION; INTERIM-FUZE ARMING WIRES, MASTER-SWITCH ARMING WIRES, AND T1404 FUZE ARMING WIRES ARE ALSO SHOWN

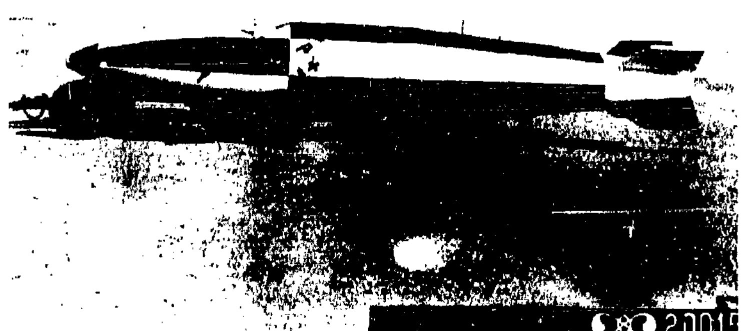


FIGURE 68

ASSEMBLED FIN-STABILIZED WARHEAD ON DOLLY

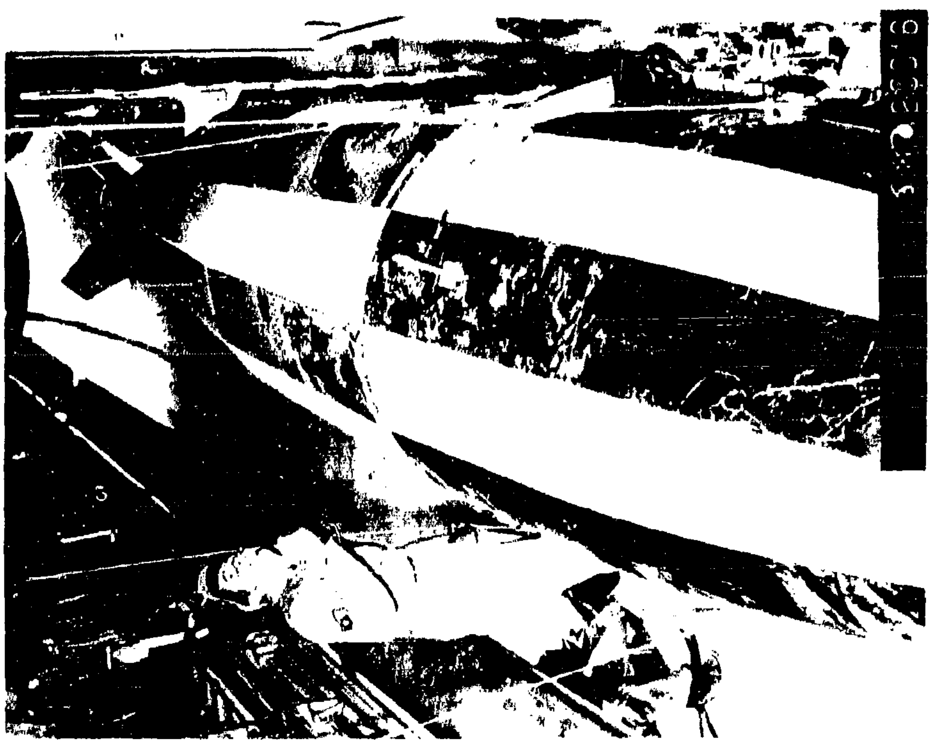


FIGURE 69

FIN-STABLIZED WARHEAD IN PLACE UNDER B-36 BOMB BAY READY FOR HOISTING INTO POSITION

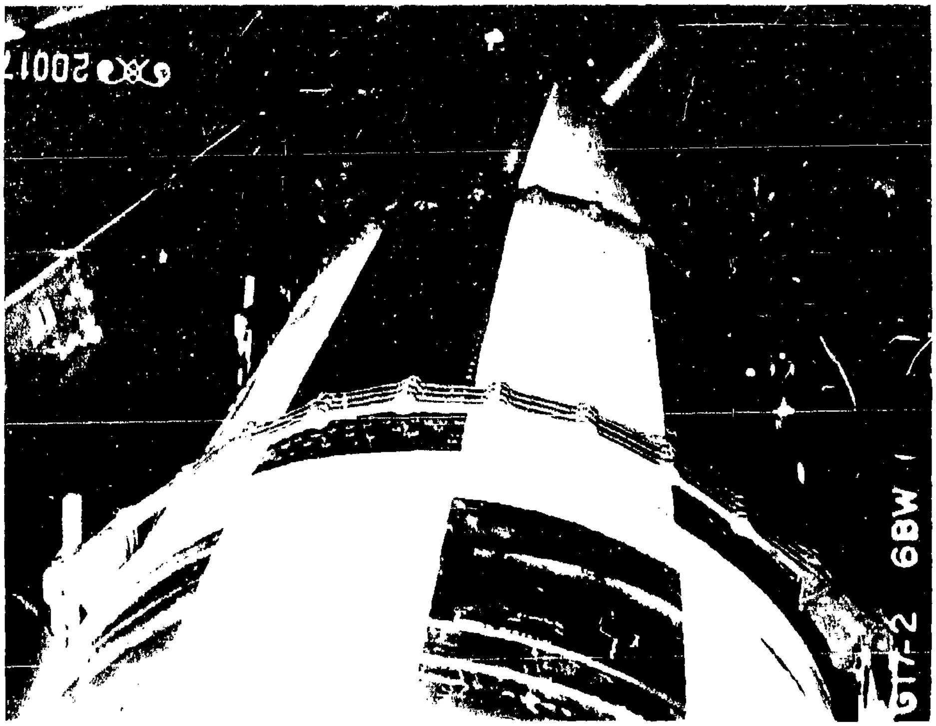


FIGURE 70

FIN-STABLIZED WARHEAD IN POSITION IN B-36 BOMB BAY SHOWING BOMB SLINGS IN PLACE UNDER CENTER SECTION

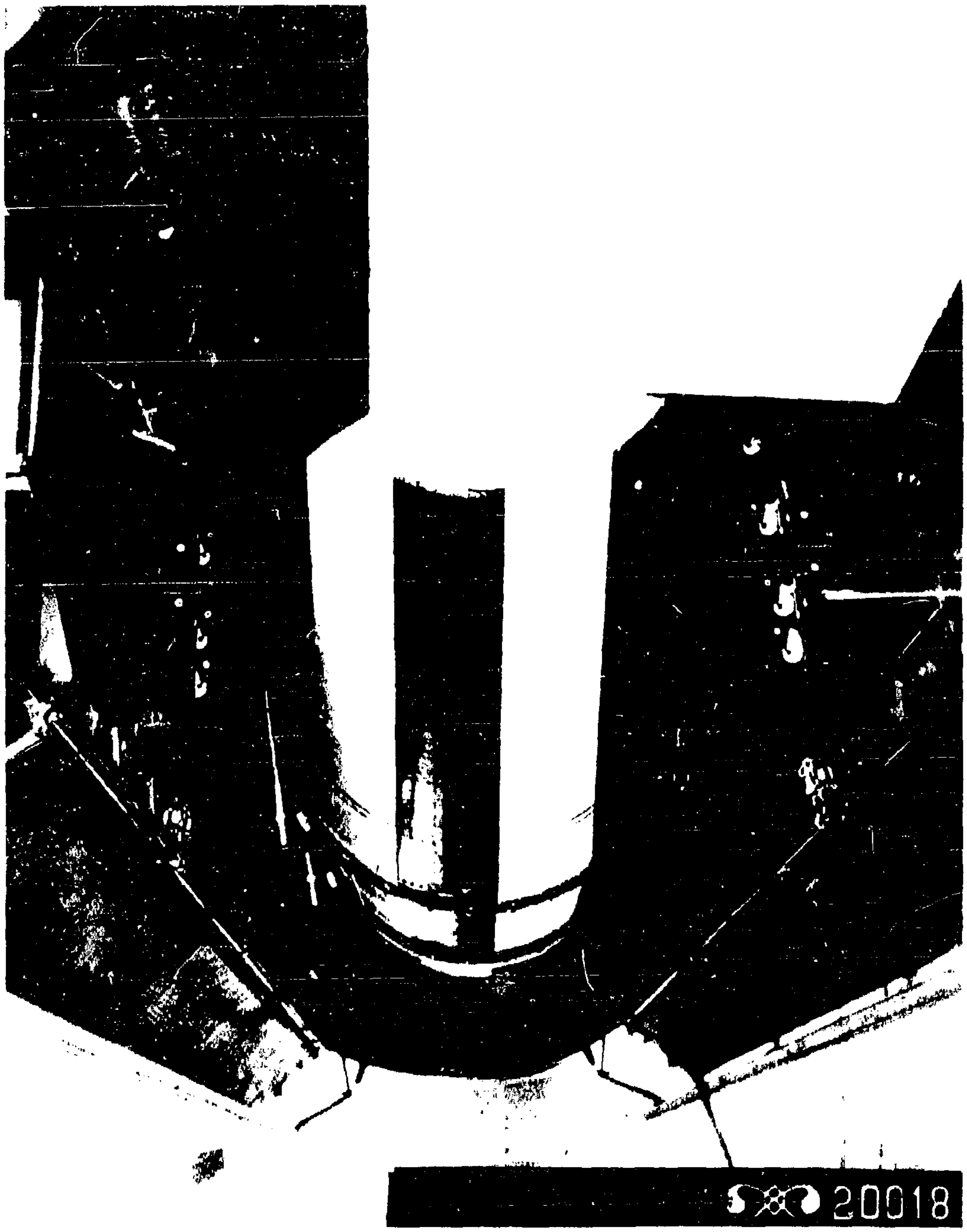


FIGURE 71

VIEW LOOKING FORWARD OF FIN-STABILIZED WARHEAD IN POSITION IN B-36 BOMB BAY SHOWING BOMB SLINGS IN PLACE

APPENDIX B

ALLOCATION OF MATERIALS FOR VARIOUS TESTS

Test	B-61A nose assembly	E54 adapter	Interim fuze	T1404 fuze	E54R6 bomb	E24R1 fuze	Bursters Live	Bursters Inert	E81 E.B.C. (a)	Type of test	Remarks
Physical and dimensional	0	15	16	0	0	0	0	0	0	Nondestructive	To be used in flight tests
Material properties	0	1	0	0	0	0	0	0	0	Destructive	Cut samples from nonusable adapter
Corrosion resistance	0	1	0	0	0	0	0	0	0	Destructive	Metal parts only on adapter
Fit test	15	15	16	7	4,590	4,590	2,448	2,142	0	Nondestructive	To be used in flight tests
Handling and transportation	0	1	0	0	306 (b)	306 (b)	0	306	0	Destructive	For Eng. Div. tests of shipping container
Assembly	15	15	16	7	4,590	4,590	2,448	2,142	60	Nondestructive	To be used in flight tests
Drop test	0	2	0	0	612 (b)	612 (b)	0	612	0	Destructive	Tests to be repeated if warranted
"G" test	0	1	0	0	306	306	0	306	0	Destructive	Tests to be repeated if warranted
Vibration	0	1	0	0	306	306	0	306	0	Destructive	Tests to be repeated if warranted
Surveillance	0	4	0	0	1,224 (b)	1,224 (b)	0	1,224	50	Destructive	Tests to be repeated if warranted
Static firing	3	3	10	0	0	0	0	0	0	Destructive	Performed by GLM Co. at GLM Co.
Flight tests A. Fin-stabilized warhead	14	14	16	6	4,284	4,284	2,448	1,836	56	Destructive	None
B. B-61A missile	1	1	0	1	306	306	306	0	4	Destructive	None
Total	18	27	26	7	7,344 (c)	7,344 (c)	2,754	4,590	110		

(a) Electric blasting caps.

(b) Total destruction is not anticipated on all units. Those which remain serviceable will carried over to other destructive quantities.

(c) Based on total destruction on preceding static tests.

APPENDIX C

SUMMARY OF RESULTS OF FIN-STABILIZED-WARHEAD TESTS

Missile number	Cluster number	Test date	Number recovered	Performance data (a)						Remarks
				A	B	C	D	E	F	
87A-3	P-1	10-7-53	0	0	0	0	0	0	0	Failed to open; impacted intact
87A-4 (b)	P-3	15-15-53	299	198	4	2	5	0	7	Bolts sheared; warhead opened prematurely
87A-6	P-5	12-15-53	0	0	0	0	0	0	0	Failed to open; impacted intact
87A-5 (c)	P-2	2-24-54	298	280	3	1	3	0	2	Normal drop; all components functioned
87A-1	P-6	7-29-54	296	246	8	5	3	13	21	Normal drop; all components functioned
87A-7 (d)	P-7	7-29-54	274	153	7	7	5	3	9	Bolts sheared; warhead opened prematurely
87A-2	P-4	-	-	-	-	-	-	-	-	Lost in fall from bomb bay to ramp

(a) Legend:
- A. All components functioned satisfactorily
- B. Ballistics satisfactory; fuze did not arm
- C. Flat lander; fuze armed
- D. Delay did not function
- E. Parachute missing or other structural damage
- F. Ballistics satisfactory; fuze armed; did not function

(b) 83 bombs found in one adapter half; 5 unidentified

(c) 9 bombs found by survey crew were not picked up in initial survey

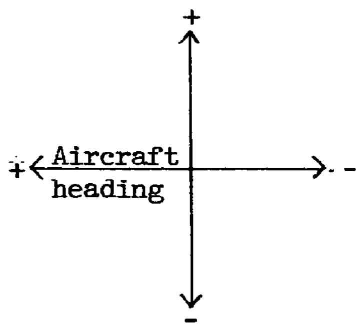
(d) 90 bombs found in one adapter half; 35 unidentifiable

APPENDIX D

FLIGHT DATA FOR FIN-STABILIZED WARHEAD (Target Elevation, 4,090 ft.).

Warhead number	Release above sea level		Separation above sea level		Range		Ballistic wind	
	Altitude	Velocity	Altitude	Velocity	Release to separation	Separation impact	Ballistic range wind	Ballistic wind cross wind
	ft.	f.p.s.	ft.	f.p.s.	ft.	ft.	f.p.s.	f.p.s.
87A-1	36,890*	558	16,590*	1,059	18,810*	3,000	-6.34	6.48
87A-4	35,870	452	13,390	990	13,495	2,250	-1.11	-30.46
87A-5	35,499	490	15,680	1,030	15,706	687	-13.71	-8.11
87A-7	37,010*	550	12,100*	1,073	20,190*	1,890*	-4.81	7.10

*Determined from radar plots



APPENDIX E

PATTERN DATA, FIN-STABILIZED WARHEAD

Warhead number	Total dimensions	Recovery	2σ-Range (length)	2σ-Deflection (width)	2σ-Area	2σ-Area	Pattern coefficient
	yd.	%	yd.	yd.	sq.yd.	%	D/R
87A-1	320 x 320	97	125.19	113.91	44,800	84	0.91
87A-4	835 x 335	98	257.24	110.28	89,100	87	0.43
87A-5	350 x 285	97	128.18	106.96	43,070	81	0.83
87A-7	335 x 335	90	140.08	139.97	61,600	85	0.999

APPENDIX F

BOMBS PATTERNS

Fig. 72, Fin-Stabilized Warhead 87A-1

Fig. 73, Fin-Stabilized Warhead 87A-4

Fig. 74, Fin-Stabilized Warhead 87A-5

Fig. 75, Fin-Stabilized Warhead 87A-7

Bomb Symbol Legend

All components functioned satisfactorily	○
Ballistics satisfactory; fuze did not arm	△
Flat lander; fuze armed	□
Delay did not function.	⊠
Parachute missing or other structural damage.	◑
Ballistics satisfactory; fuze armed; did not function .	◪
90 bombs and cluster adapter.	✡
83 bombs in cluster	◬ (triangle in circle)

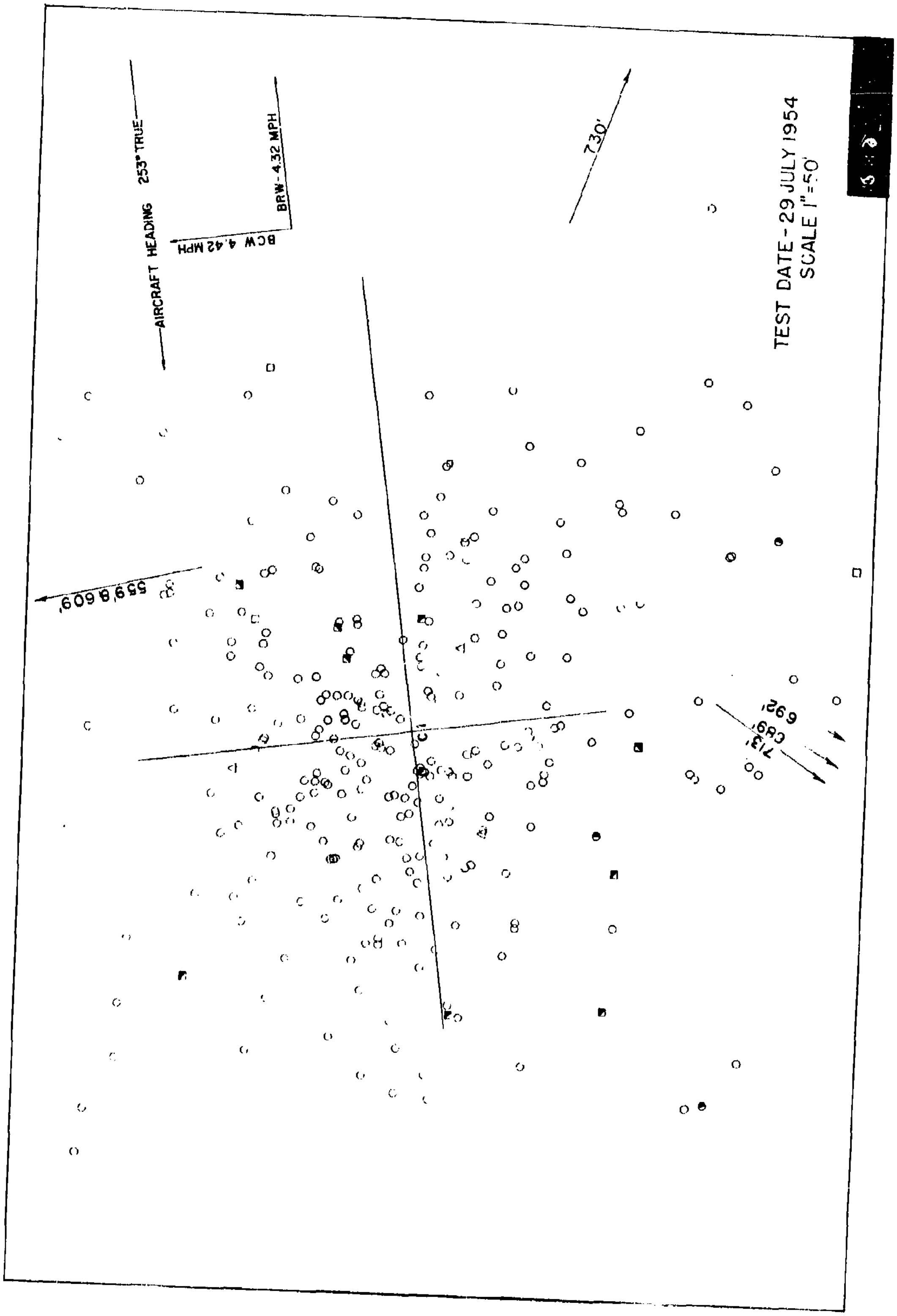


FIGURE 72

FIN-STABILIZED WARHEAD 87A-1

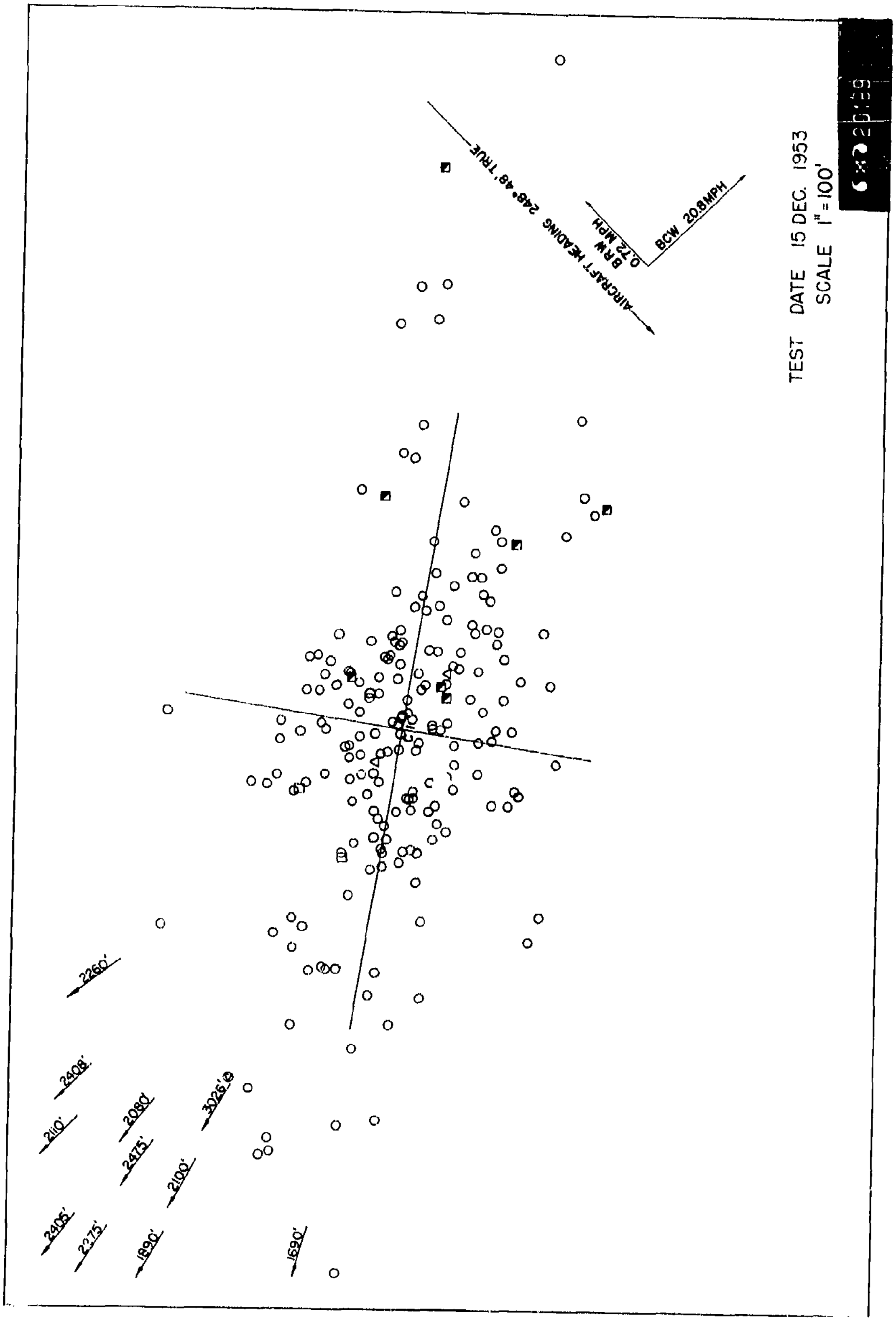


FIGURE 73

FIN-STABILIZED WARHEAD 87A-4

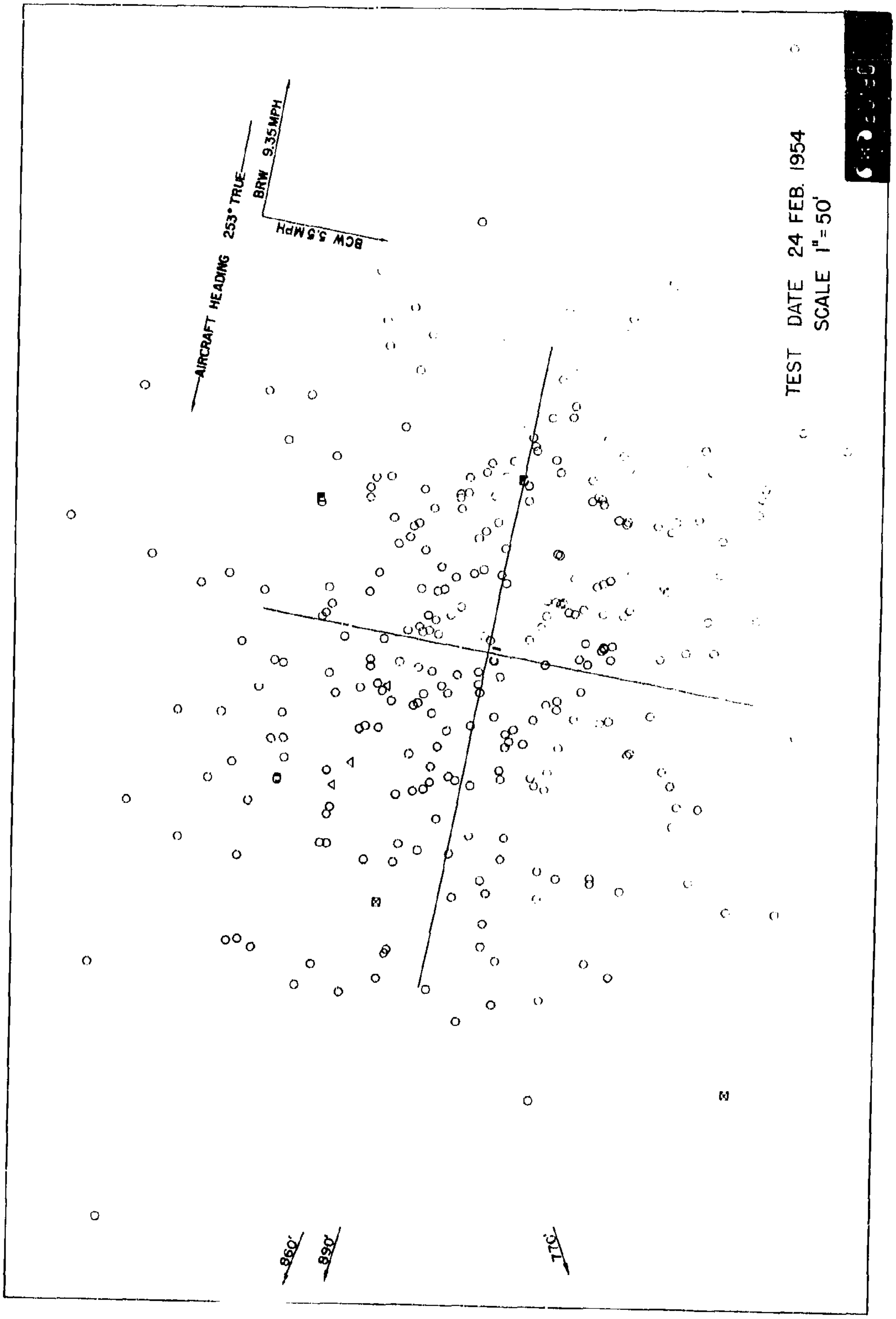


FIGURE 74
FIN-STABILIZED WARHEAD 87A-5

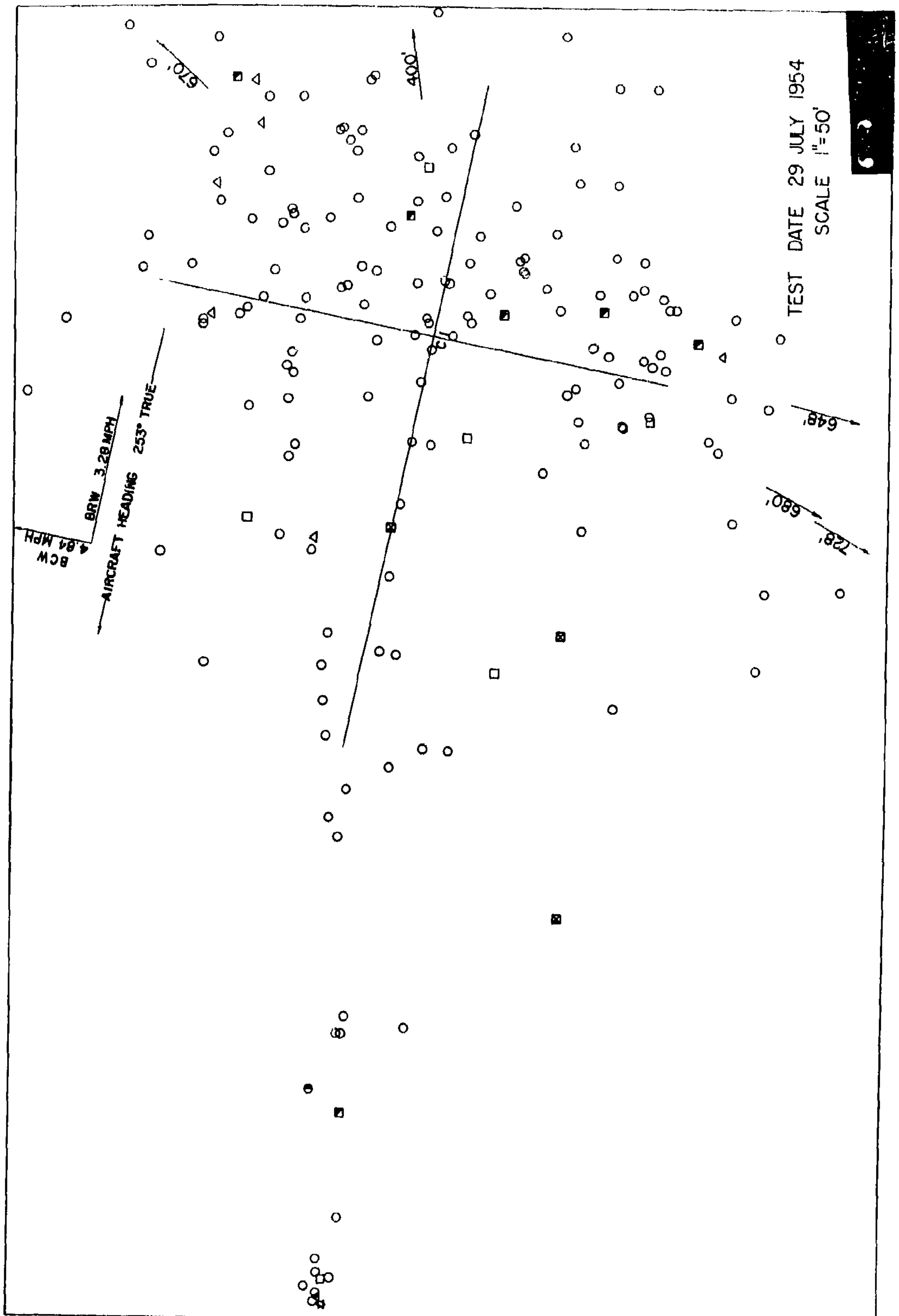
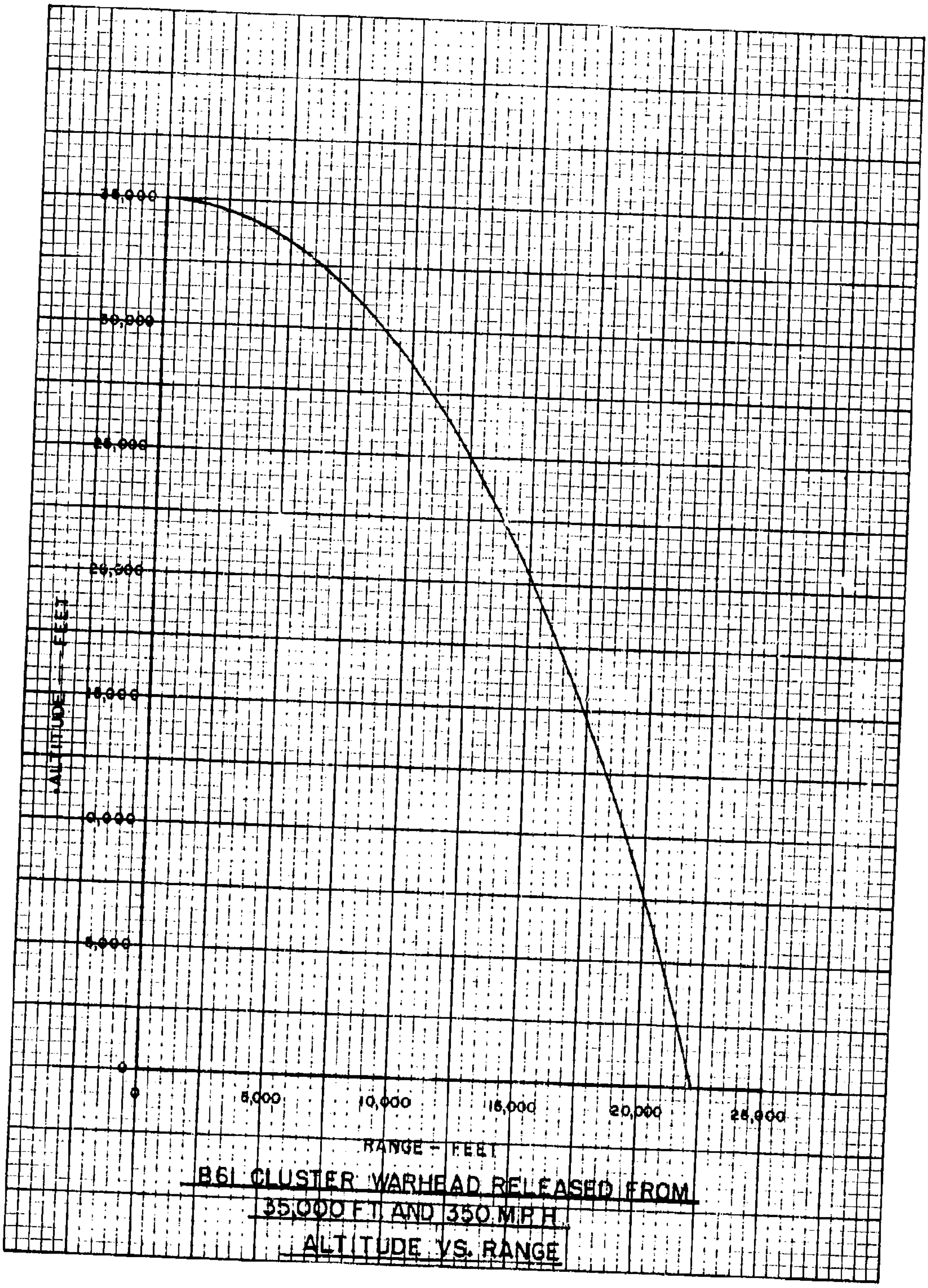


FIGURE 75

FIN-STABILIZED WARHEAD 87A-7

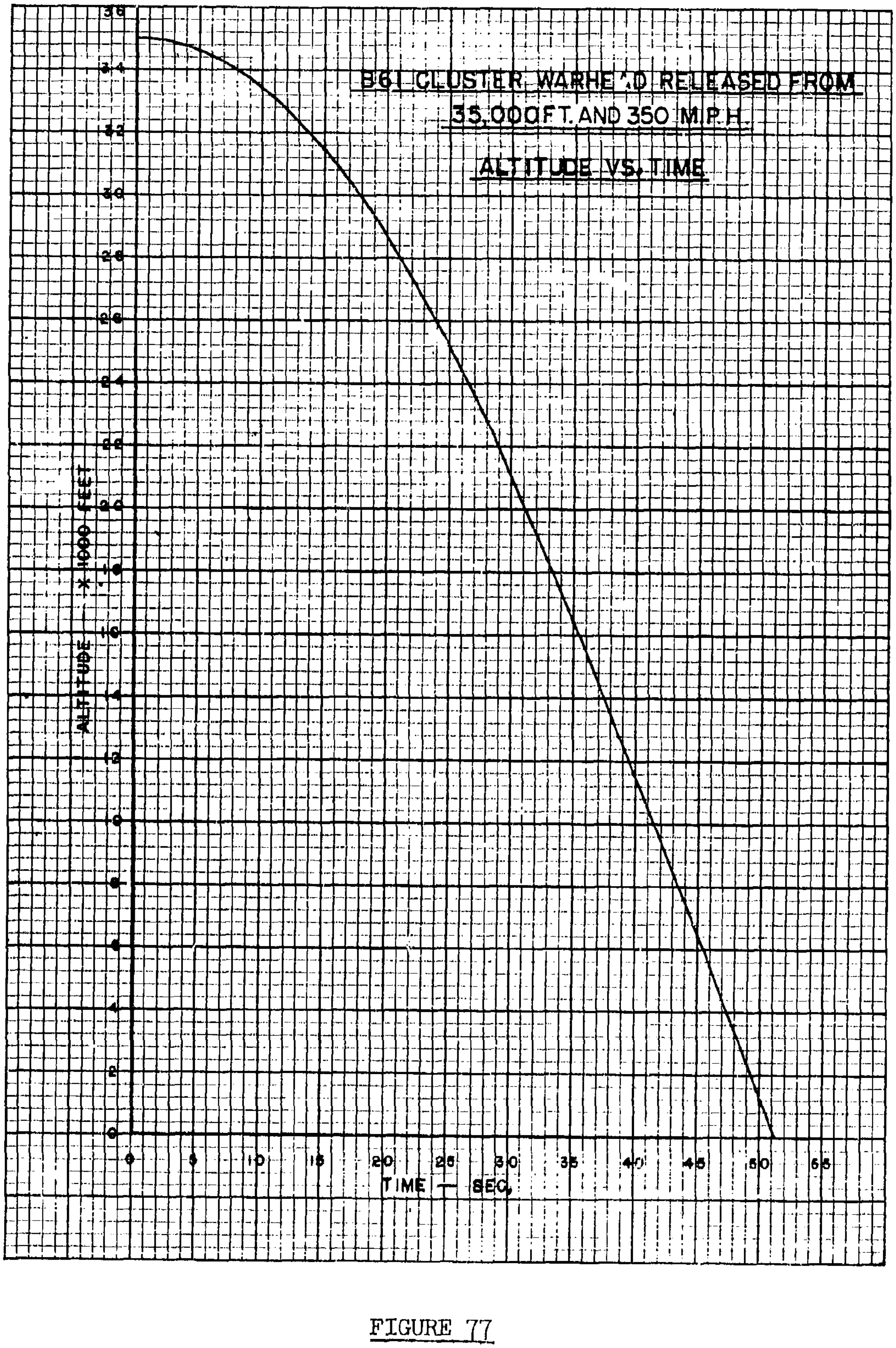
APPENDIX G

FIN-STABILIZED WARHEAD BALLISTIC DATA



B61 CLUSTER WARHEAD RELEASED FROM
35,000 FT. AND 350 M.P.H.
ALTITUDE VS. RANGE

FIGURE 76



B61 CLUSTER WARHEAD RELEASED FROM
35,000 FT. AND 350 M.P.H.
ALTITUDE VS. TIME
ALTITUDE × 1000 FEET
TIME — SEC.
0
5
10
15
20
25
30
35
40
45
50
55

FIGURE 77

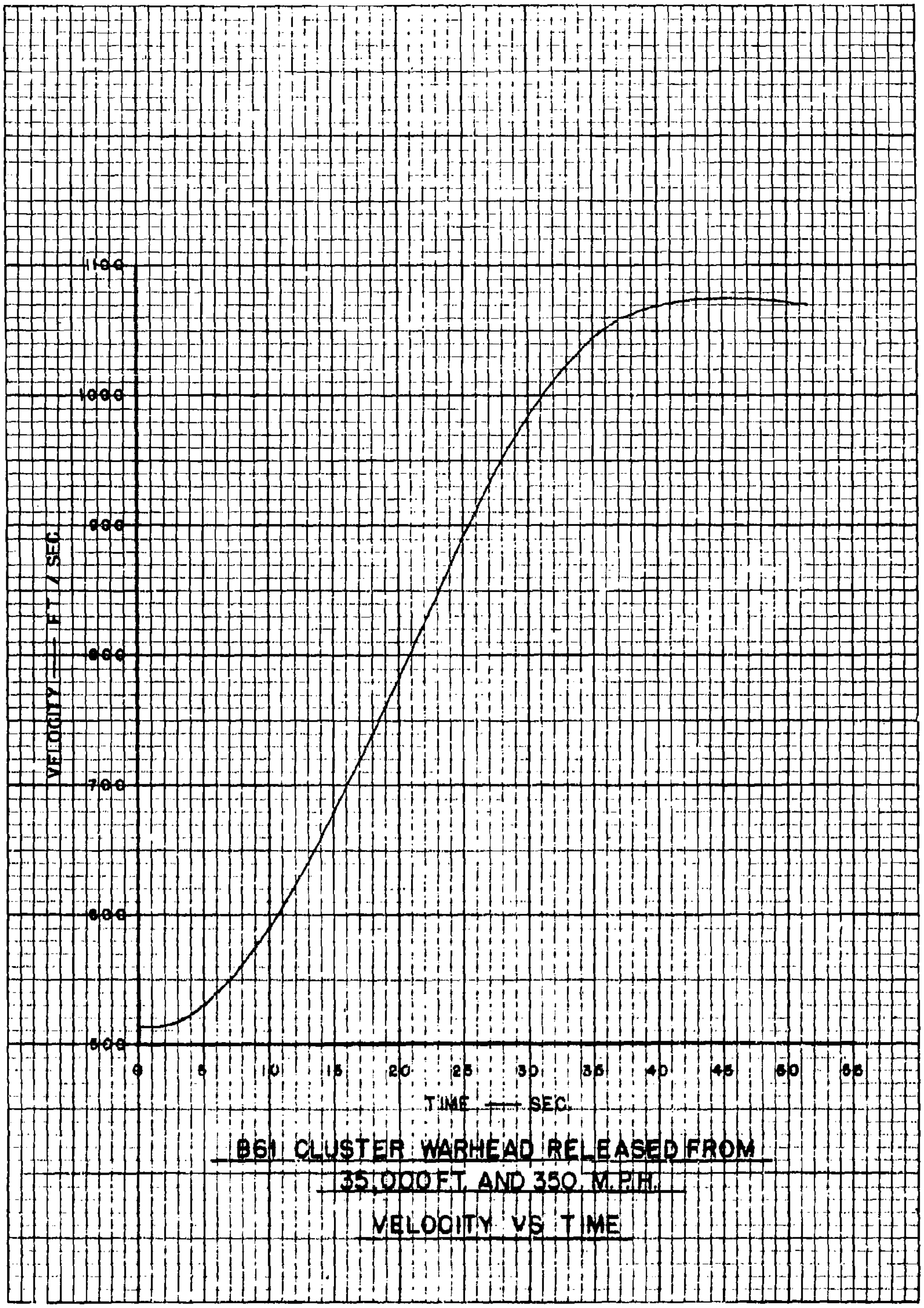

VELOCITY —— FT / SEC.
1100
1000
900
800
700
600
500
0
5
10
15
20
25
30
35
40
45
50
55
TIME —— SEC.
B61 CLUSTER WARHEAD RELEASED FROM
35,000 FT. AND 350 M.P.H.
VELOCITY VS TIME

FIGURE 78

APPENDIX H

WARHEAD OPENING POINT CORRECTED FOR BALLISTIC WIND

Fig. 79 gives a method for determining the point at which the fin-stabilized warhead should be opened, taking into account the effect of ballistic wind. Knowing the ballistic wind and the desired warhead opening altitude, the amount of drift can be determined. Combined with the direction of the ballistic wind, the offset point with respect to the target can be established.

Example

Given:

Ballistic wind velocity - 44 m.p.h.

Ballistic wind direction - 135°

Opening altitude - 8,500 ft.

From the graph, the intersection of the opening-altitude line with the ballistic-wind line is projected horizontally to the abscissa to give a drift reading of 3,640 ft. This distance is measured from the target on a line bearing 135° clockwise from the line of flight and establishes the warhead opening point.

The graph is applicable only to the fin-stabilized warhead and would have to be redetermined for the missile or other test vehicle.

Data used in plotting the graph were obtained from ballistic tables prepared by Ballistic Research Laboratory, Aberdeen Proving Ground.

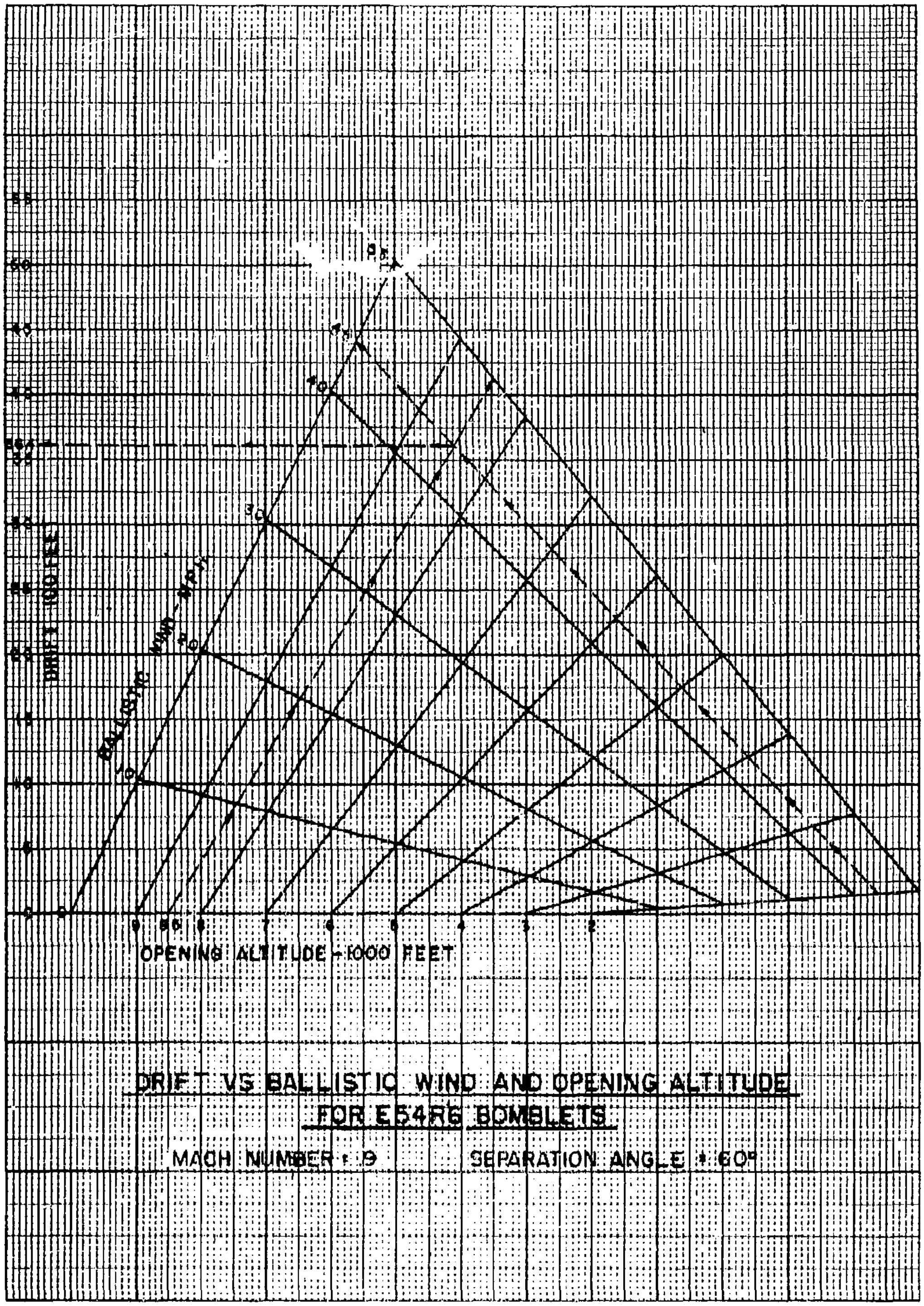

DRIFT (100 FEET)
BALLISTIC WIND - M.P.H.
OPENING ALTITUDE - 1000 FEET
DRIFT VS BALLISTIC WIND AND OPENING ALTITUDE
FOR E54R6 BOMBLETS
MACH NUMBER : .9
SEPARATION ANGLE : 60°

FIGURE 79

APPENDIX I

LIST OF DRAWINGS COVERING B-61A CHEMICAL WARHEADS AND RELATED EQUIPMENT

Glenn L. Martin Company Drawings:

87-2000000	Warhead Assembly, Complete, Fin-Stabilized Warhead
87-2000001	Nose Section Assembly, Complete, Fin-Stabilized Warhead
87-2000002	Shts. 1 - 3, Frame Assembly, Nose Sta. 40.125 to 118.375
87-2000003	Shts. 1 - 5, Center Section, Fin-Stabilized Warhead
87-2000004	Shts. 1 - 4, Aft Section Assembly, Fin-Stabilized Warhead
87-2000005	X-Frame Assembly, Nose Bomb Support
87-2000006	Cap Assembly, Nose, Fin-Stabilized Warhead
87-2000007	Bulkhead, Center Section, Sta. 119.906, Fin-Stabilized Warhead
87-2000008	Frame - Sta. 128, Center Section, Fin-Stabilized Warhead
87-2000009	Frames - Sta. 40.125, 41.875, and 118.375, Fin-Stabilized Warhead - Nose Sect.
87-2000010	Frame - Sta. 58.750, Fin-Stabilized Warhead
87-2000011	Frames - Sta. 93 and 106.250, Fin-Stabilized Warhead - Nose Section
87-2000012	Frames - Sta. 74.969 and 78.219, Fin-Stabilized Warhead
87-2000013	Channel, Nose, X-Frame
87-2000014	Web, Nose, X-Frame
87-2000015	Fitting, Nose, X-Frame
87-2000016	Longeron, Upper and Lower, Nose
87-2000017	Fitting, Nose Trunnion, Sta. 76.594
87-2000018	Bolt, Special, Fin-Stabilized Warhead
87-2000019	Frame - Sta. 176, Center Section, Fin-Stabilized Warhead

87-2000020	Splice Fitting, Nose, Sta. 118.375
87-2000021	Stringer, Nose, Sta. 78.219 to Sta. 118.375
87-2000022	Clip, Longeron, Nose, Sta. 78.219
87-2000023	Web, Sta. 74.968 to Sta. 78.218, Nose
87-2000025	Hoist Fitting, Bulkhead 119.906, Center Section
87-2000026	L.E. Fin Tip Former, Fin-Stabilized Warhead
87-2000027	L.E. Fin Tip Former, Fin-Stabilized Warhead
87-2000028	Drag Pin, Center Section, Fin-Stabilized Warhead
87-2000029	Fitting Assembly, Sta. 120, Fin-Stabilized Warhead, Lower
87-2000030	Fitting Assembly, Sta. 120, Fin-Stabilized Warhead, Upper
87-2000031	Fittings, Tension Bolt, Sta. 128
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87-2000033	Hoist Lug, Bulkhead 119.906, Complete Nose
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Chemical Warfare Laboratories Drawings:

D314-23-3235	Plastic cluster Adapter and Lock Mechanism
D314-23-3236	Adapter, Details
D314-23-3237	Cluster Adapter Mold

D314-23-3238	Pre-Molded Insert Mold
D314-23-3239	Inner Liner & Spacer Arrangment, Bomb Arrangement 3
D314-23-3240	Sht. 1 & 2, Cluster Adapter Lay-Up
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D314-23-3242	Mechanism, Locking, Details
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D423-4-101	Warhead Loading Stand, Assembly and Details
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<u>List of Material</u>

23 Ea. - Fin-stabilized Warheads, 87A-2000000

3 Ea. - B-61A Chemical Warhead Nose Casings, 87A-2000001

31 Ea. - Adapter, 3,000-lb., Cluster, E54, D314-23-3235

2 Ea. - Cluster Handling Clamp, D314-34-101

2 Ea. - Sling Assembly, 87A-2000041

1 Ea. - Clustering Stand

2 Ea. - Warhead Loading Stand, D423-4-101

2 Ea. - Shipping Container Components, Unassembled

1 Ea. - Warhead Static Test Stand

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